FIREFIGHTING PRINCIPLES & PRACTICES

William E. Clark

SECOND EDITION

Fire Engineering Books & Videos

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FIREFIGHTING PRINCIPLES & PRACTICES

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SECOND EDITION

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William E. Clark

Fire Engineering Books & Videos
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Foreword

ONE OF THE best books of the fire service has just been made better. Bill Clark has revised and updated *Firefighting Principles and Practices*. Now included in this informative textbook are vital pieces of the firefighting puzzle: the incident command system, hazardous material containment during firefighting operations, the pros and cons of positive-pressure ventilation, trench cutting a roof, and how to conduct an efficient secondary search and rescue operation.

If you had to describe this book in ten words or less, "it tells you how to fight a fire." It is written for the fire officer and for any firefighter who aspires to become a fire officer.

This text is better than an encyclopedia. Just think of any firefighting topic, and look it up in the index; it is listed there. Everything you want to know about the principles and practices of firefighting can be found in this book.

I would never write an article for *Fire Engineering* about a firefighting subject without first checking out what Bill Clark's book says about it. It's a great book, written about a practical subject by a practical man.

1990

VINCENT DUNN
Deputy Chief, FDNY

Foreword to the First Edition

FEW MEN ever get the opportunities to become as deeply involved with the fire service as William E. Clark, director, Florida State Fire Service Training. He started out in New York City in 1937 as a probationary fireman and left the department 20 years later as a battalion chief. His next fire service assignment took him to Bound Brook, N.J., where he became an industrial fire chief for the sprawling Union Carbide plant. From there he went to Wisconsin to become the state fire service training supervisor. But after ten years of that, another opportunity beckoned, and he became fire director, Prince Georges County, Md., which job he left to become head of Florida's Fire Service Training.

In this varied career, Clark also found time to become founder of the International Society of Fire Service Instructors (serving once as president) and chairman of the training and education committee, International Association of Fire Chiefs. He is also well known as a lecturer and seminar leader throughout the training circles of the United States, Canada, and several other countries.

When Fire Engineering decided to expand its library series with "Fire Fighting Principles and Practices," it was only natural that William E. Clark's name, as author, came to mind. His background, of course, made him eminently qualified, and he has a facility with words that few fire fighters possess. But beyond this, he is dedicated to the proposition that the major function of a fire department is to fight fires—everything else is secondary. And it was with this attitude that he sat down to write the book.

The principles and practices of fire fighting were set down, or perhaps we should say have evolved, over the past 100 years or so and as Clark makes clear, there is nothing new under the sun. But we feel that never before have these principles and practices been set down under one cover as he has set them down so clearly and succinctly.

James F. Casey

Fire Engineering, 1974

Preface

THE READER OF this book who is familiar with the first edition will find that many changes have been made so that it may continue to help serious students of fire protection, who are studying for personal advancement or the improvement of their knowledge. Progress in the fire service and the increasing complexity of the fire problem have led to a demand for a new edition, to bring us up to date in combating hostile fire.

While it is true that fire department administrative procedures are important, the fire department doesn't exist merely to be well run. Administrative decisions can be reached after due deliberation and consultation—and can be reversed if found wanting—but fireground decisions have to be made quickly. Time does not allow the luxury of consultation and deliberation. The decisions are usually irreversible, and the consequences of error can be disastrous. Unlike executives in business and industry, the fire officer must base his decisions on hastily gathered information, and, although he is dealing with laws of chemistry and physics, he cannot be certain of how these will affect the particular situation confronting him. It is safe to say that every fire officer reading these words will soon be confronted with a fire situation different from anything that he has ever encountered previously, and that he will see things happen there that he has never observed before.

One of the most expensive schools in the world is the school of firefighting experience: it costs billions of dollars each year. And, by the time a fire officer has acquired a reasonable amount of operational knowledge through experience, the cost of the property destroyed in the process makes it a high price to pay. Therefore, knowledge must be acquired through training as well as experience.

An experienced officer in the fire department of a medium-sized city once told me, "I have never seen a fire lost for lack of an extinguishing agent, lack of equipment, or lack of personnel, but I have seen many lost for lack of proper strategy or tactics."

The truest test of a fire officer is the use of strategy and tactics in a fire situation. The line officer, no matter what the rank, has tactical responsibilities. It is the aim of this book to help in arriving at the correct solutions to this most important function of that demanding and many-faceted position.

We make no claim that this book presents any radically new concepts. After all, we are dealing with problems and principles which have existed for centuries. Our aim here is to make them more clearly understood. Most of the methods advocated have stood the test of time in some of our largest American fire departments and are based on lessons learned there; however, the acquisition of knowledge through experience is not limited to any single fire department, no matter how big. Lessons are learned in many places, and imaginative thinking and original ideas can crop up anywhere, including some of our smallest departments. Many of the ideas described here originated in such sources.

I well recognize that some slight differences exist among fire departments as to tactics and procedures, and that building types and construction features may vary somewhat in different sections of the United States and Canada. I decided that, rather than trying to avoid these matters, it would be better to mention them, not just for the benefit of those in the sections involved, but also for the other readers who might gain from the information. The reader is advised to adapt the precepts offered here to fit his own circumstances and the policies of his fire department.

Fire is so elemental and fundamental to life on this earth that it is a source of wonder that man has not learned to master its destructive force. It is not claimed, or even thought, that this book would establish that mastery. The best we hope for is that it may stimulate a thought that could lead to a significant advance in limiting fire's destruction.

I wish to repeat my thanks to those who helped with the first edition, especially Jim Casey, and to add thanks to those who assisted with the new edition, especially Barbara Sidney Douglas, and, of course, to thank once again my wife Ellen for her help and patience.

William E. Clark

About the Author

WILLIAM E. CLARK has long emphasized strategy, tactics, and safety in the fire service. During his 20 years in New York City's fire department, he rose from the ranks to battalion chief; has been an industrial fire chief; initiated the statewide fire service training system in Wisconsin; and became the first head of county fire services in Prince Georges County, Maryland.

Bill has lectured throughout the United States, Canada, Asia, and South America; has taught fire administration, and strategy and tactics. He has also acted as an expert witness on fire behavior and firefighting tactics in civil and criminal cases. He founded the International Society of Fire Service Instructors and became its president and has served as chairman of the National Fire Protection Association committee on protective equipment for firefighters and chairman of the International Association of Fire Chiefs training and education committee. One of only five Americans admitted to the highest level of the British Institution of Fire Engineers, he was chairman of its North American branch.

In addition to the first and second editions of this book, William Clark has published nearly 50 articles in national fire magazines and has prepared training manuals for federal, state, and industrial fire training programs.

In 1957, he was the first to advocate yellow as the safest color for firefighter garments. During the 1960s, he led the campaign for safer and more reliable breathing apparatus, indicating the faults of filter masks, and stressing the need for improved self-contained breathing apparatus. At present, he urges that emphasis on safety should shift from hardware to training.

FIREFIGHTING PRINCIPLES & PRACTICES

1

Fire Behavior

IF AN understanding of the enemy is fundamental to military operations, it is equally so in fighting fire. Firefighters should be armed with sufficient knowledge of their enemy, fire, to protect themselves from it and to overcome it efficiently. This preparation calls for an understanding of the combustion process and its principal requirements and effects.

Of all the chemical elements which combine to make up this world, three are of particular interest to firefighters: carbon, oxygen, and hydrogen. Most of the common materials that burn contain carbon; these include paper, wood, cloth, plastics, and flammable liquids. Hydrogen is also found in many fuels, often united with carbon to form hydrocarbons. We live in a sea of air, which contains about 21 percent oxygen. Oxygen is necessary to support human life—and also fire; without it, there would be neither. Oxygen also combines with hydrogen to form water.

COMBUSTION

Combustion (which means fire) occurs when oxygen combines with a combustible material so rapidly as to generate heat.

Solid materials are made up of closely packed molecules; the closer they are packed, the heavier the material. Solids possess both shape and volume. Liquid molecules are less densely packed, so liquids have volume but no shape, thus taking the shape of whatever contains them. The molecules of gases are widely separated and consequently have neither shape nor volume.

Molecules move, and when they are heated their speed of motion increases. The more their temperature increases, the more rapidly they move; the more rapidly they move, the greater is their chance of combining with the molecules of another element by colliding with those molecules. Thus oxygen molecules in the air combine with fuel molecules to form oxides.

This process of molecules combining releases energy in the form of heat, and, since unwanted, excessive heat is the basic problem of the fire service, we should learn to regard it as energy, and become well acquainted with how this type of energy can be produced, transferred, and reduced. There are several forms of energy: mechanical, electrical, chemical, and nuclear. Potential energy is the energy latent in a body; kinetic energy is that energy which is caused by motion. Combustible substances contain potential energy, which is released as heat and, sometimes, light when the substances burn.

Heat is actually a form of energy in transit. Inasmuch as nature always strives to maintain equilibrium, heat is always moving from warmer objects to cooler ones, which absorb the heat until the objects become equal in temperature. There is no such thing as cold. Cold is merely a relative term, to denote a lower than normal degree of heat. For instance, if Minneapolis and Miami both had a temperature of 40 degrees Fahrenheit in the middle of February, the people of Minneapolis would say, "It is warm today," while those in Miami would remark that it is cold—because each would be comparing the temperature with their usual average norm for the day.

Heat and temperature are not identical. The total heat energy of a body (substance) is the sum of the kinetic and potential energies of all its molecules; heat energy is measured in calories in the metric system and British thermal units (BTUs) in the English.

Temperature is a measure of the average molecular velocity only; thus it indicates the *intensity* of the heat at a given moment and location. It is not dependent upon the amount of heat that a fuel contains. Temperature is usually measured on either the Celsius (Centigrade) or the Fahrenheit scales, but it can also be measured in degrees Kelvin or Rankine (Figure 1.1). Degrees Kelvin use the same intervals as degrees Celsius but begin at absolute zero. Degrees Rankine use the same intervals as degrees Fahrenheit but start at absolute zero. Each degree Celsius or Kelvin equals 1.8 degrees Fahrenheit; therefore a rough but quick way to convert from one scale to another when discussing high temperatures of fires is to estimate that

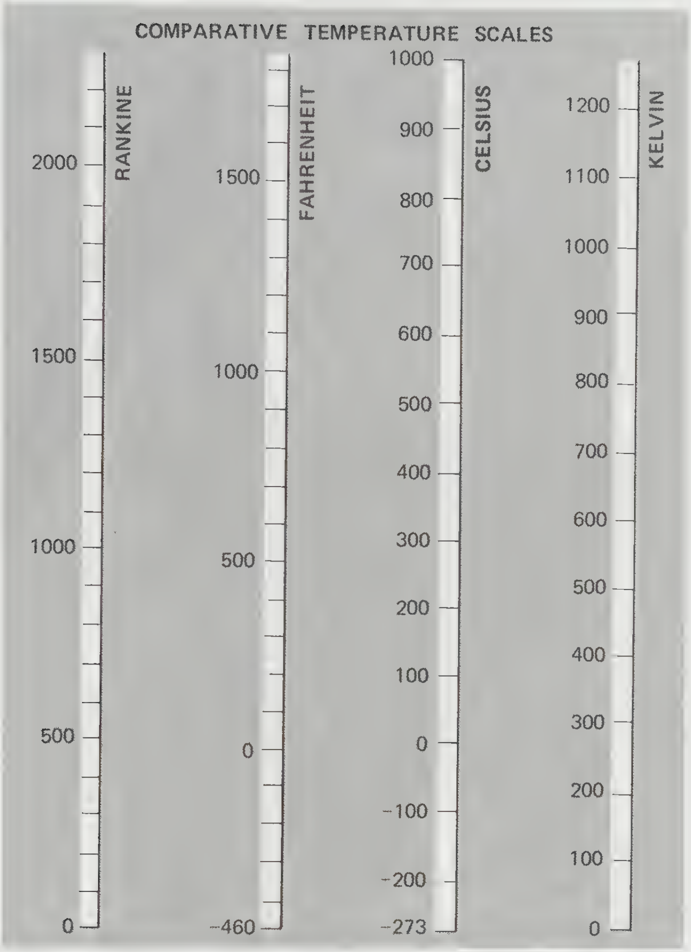


Figure 1.1. *Comparison of the most common scales for temperature measurement.*

the Fahrenheit temperature is slightly less than double the Celsius. In fact, 10 percent less than double is fairly accurate.

Fire should then be understood as an intricate network of molecular events, resulting in the release of energy in an exothermic reaction. (*Exothermic* means that heat is emitted; *endothermic* means heat is absorbed.)

Energy is never created or destroyed, but one form of energy can be converted to another. Thus any kind of energy (such as electrical, chemical, or mechanical) can be converted to heat and start a fire. Once started, the fire is a form of chemical energy releasing still more heat, which in turn excites the molecules of the burning material to move rapidly and combine with oxygen, thus propagating the fire.

For years the "Fire Triangle" has served as an excellent teaching tool to illustrate both the mechanisms of fire origin and extinguishment (Figure 1.2). The three legs of the triangle represent the three prerequisites for a fire, namely:

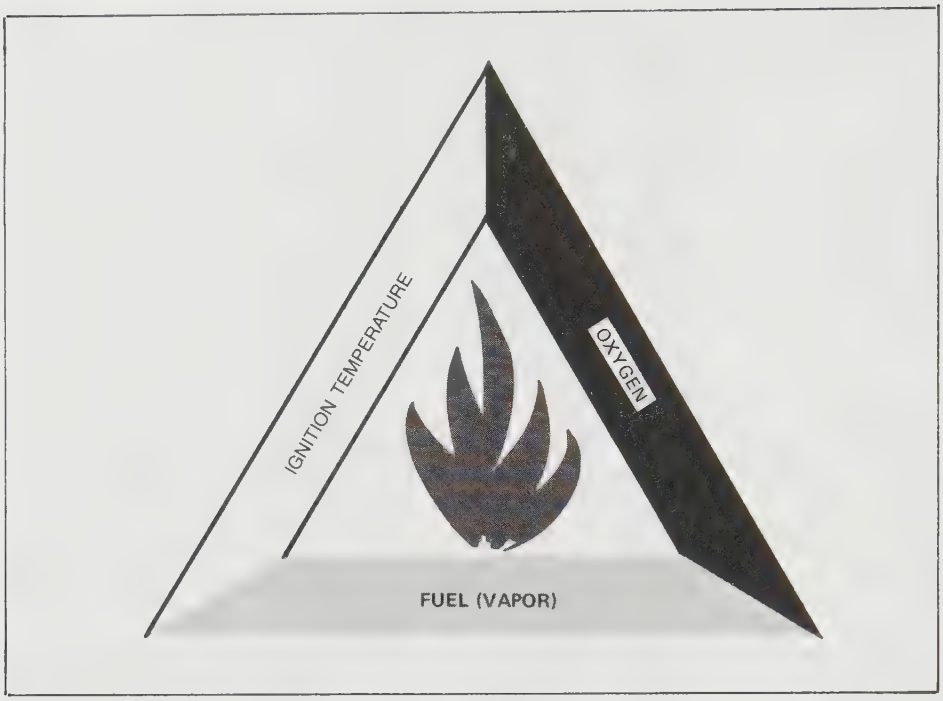


Figure 1.2. *The fire triangle requires three components, and removal of one leg of the triangle will extinguish the fire. Water removes fuel by cooling burning material to the point at which it ceases to give off flammable vapors.*

1. Oxygen
2. Fuel
3. Ignition temperature

If these prerequisites are brought together, a fire results. If one or more of them is removed, the fire is extinguished.

The famed triangle is an excellent basis for establishing an understanding of fire, but it is not truly complete. In flaming combustion, there is a fourth element, free chain reactions, which should be considered in order to gain an understanding of all the processes by which fire can be extinguished. In 1962, Walter M. Haessler suggested that a tetrahedron is more truly representative of a fire than is the triangle (Figure 1.3) when speaking of flaming combustion.

According to Haessler, the molecular combustion reaction occurs by a transfer of electrons. In this process, an oxidizing agent (usually oxygen) adopts electrons, and thereby becomes reduced. The reducing agent (called a fuel) surrenders electrons and thereby becomes oxidized. The end products, consequently, are neutral and more stable. The reaction manifests itself by emitting energy. The process is accelerated at elevated temperatures to a self-sustaining level (Figure 1.4).

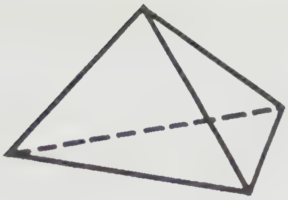
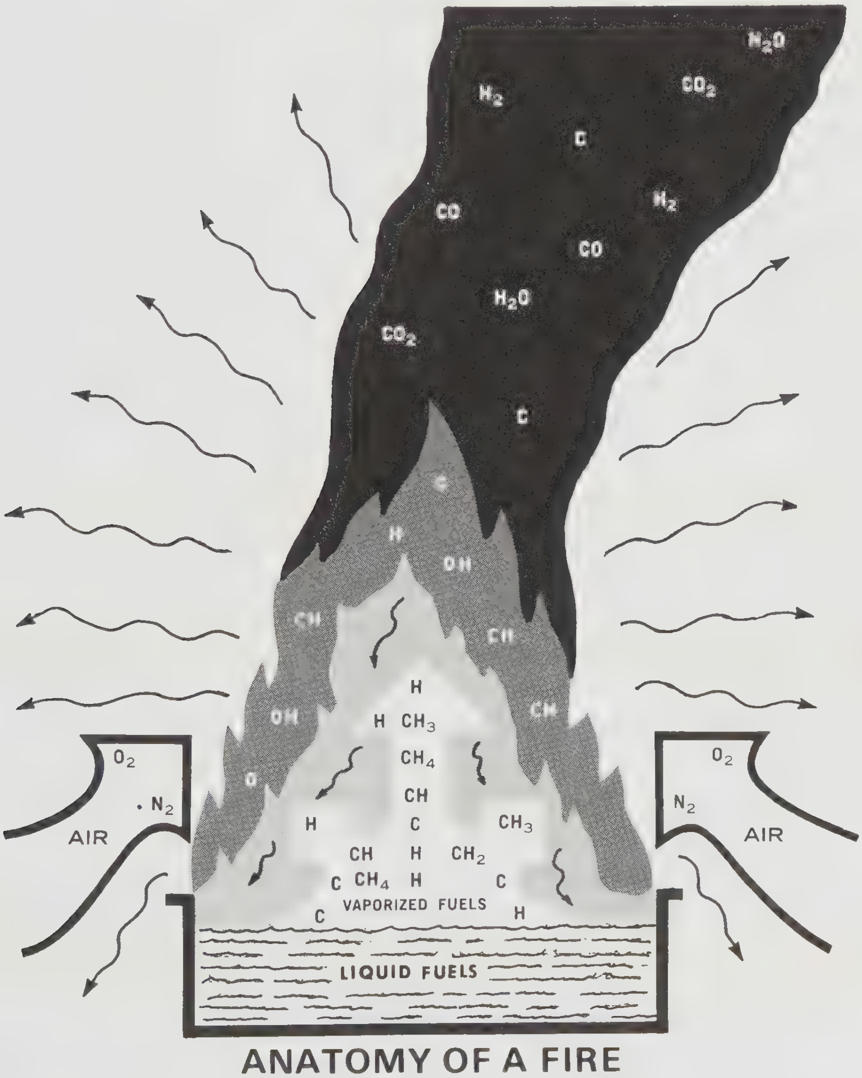


Figure 1.3. *Flaming combustion needs a tetrahedron, a four-sided figure, in which each side touches the other three. The sides of the fire tetrahedron are:* oxygen, temperature, fuel (vapor), *and* uninhibited chain reaction. *Haessler's theory is that certain agents, such as the halons and dry chemicals, extinguish fire by interrupting the chain reaction.*


H_2O
H_2
CO_2
C
CO
H_2
CO
H_2O
CO_2
C
C
H
OH
CH
CH
OH
CH
O
H
H CH_3
CH_4
CH
C
H
O_2
. N_2
AIR
O_2
N_2
AIR
H
CH_3
CH
CH_2
C CH_4 H
C
C
VAPORIZED FUELS
H
LIQUID FUELS
ANATOMY OF A FIRE

Drawing by Walter M. Haessler

Figure 1.4. *This illustration by Haessler uses burning liquid. Solids would behave the same.*

Fires have two general forms: flaming and non-flaming. The latter is represented by the slow surface-glow combustion which takes place when charcoal burns. This type of combustion uses a direct union of oxygen and fuel source without the formation of intermediate gases. Flaming combustion has a fourth prerequisite. A number of intermediate combustion products are formed and consumed; they are composed of free ions, molecular fragments termed free radicals, electrons, and so on. The interplay of these active species is a necessary part of the combustion process. Hence there is the fourth prerequisite: free chain reactions.

With the tetrahedron, Haessler points out, explanations of the effectiveness of various gaseous, liquid, and solid extinguishing agents become more apparent. The electrical nature of fire stands out. Flame velocities assume a greater importance. Explosion suppression phenomena become better understood. By this means, we can arrive at more effective firefighting agents and techniques.

Although any substance that can unite with oxygen in an exothermic chemical action is called a fuel, most solids and liquids must first vaporize in order to burn; therefore, they are really fuel sources, and it is the vapors they give off that become the actual fuel which unites with oxygen. Technically, vapors and gases differ to the extent that vapors are formed by the evaporation of solids and liquids, while gases are normally gaseous at ordinary temperatures. Once generated, however, vapors behave as gases do. The terms are used interchangeably.

Gas molecules are separated by relatively large spaces. These molecules move in a random manner, with the average that move in one direction equal to the average that move in any other direction. As a gas is heated, molecular action increases. If the gas is contained, the impact of the molecules against the inside walls of the container creates pressure. If the gas is not contained, the increase in molecular motion causes it to rise. It will increase $1/460$ of its volume for each rise in temperature of one degree Fahrenheit or, if contained, will increase its pressure by $1/460$* (Charles' Law). This process is why fire gases rise and why gases will burst their containers when heated sufficiently.

As temperature is increased, so is the rate of burning, because the molecules move faster and collide more frequently and violently.* The rate of reaction is roughly doubled for each 18-degree Fahrenheit rise in temperature; however, there are other factors which also influence conbustion; one of these factors is the concentration of molecules. If the concentration is doubled, the burning rate doubles. That is why higher concentrations of oxygen mean a faster-burning fire, and a very low oxygen concentration will result in the fire's dying out. Another factor is surface contact of the fuel source and oxygen. The more surface exposed, the higher the rate of combustion. Also, it is believed that some substances can act as catalysts and speed combustion without joining in it. (Others can act as catalysts which retard combustion.)

If the molecular reaction is rapid enough, some of the energy will appear as flame. The size and shape of the flame depend on how far the fuel molecules must travel to unite with oxygen.

When substances burn (unite with oxygen), oxides are created, the type depending on the molecules of the fuel. Since most of our common fuel sources, such as wood, contain hydrogen and carbon, they produce mostly water (in the form of steam) and carbon dioxide.

$$2H_2 + O_2 \rightarrow 2H_2O \qquad \text{(water)}$$

$$C + O_2 \rightarrow CO_2 \qquad \text{(carbon dioxide)}$$

Theoretically, each pound of carbon should combine with oxygen to make 2.6 pounds of CO_2, and each pound of hydrogen should combine with oxygen to produce eight pounds of water, which would be the result of perfect and complete combustion. At fires, however, combustion is rarely perfect or complete. For instance, wood decomposes, when heated, into carbon dioxide, carbon monoxide, water, alcohols, ketones, aldehydes, and carbon particles; these decomposition products are usually combined to form what is called smoke.

Fuel sources other than wood have different molecular structures and therefore give off other combustion products; however, since most of them contain large amounts of carbon, they will give off carbon dioxide and carbon monoxide. This fact is true of common fuel sources such as paper, cloth, and plastics. Plastics are basically hydrocarbons and contain large amounts of hydrogen and carbon (after all, they were once crude oil). When plastics burn, they produce large amounts of carbon dioxide, carbon monoxide, and water, but some have additives which will contribute other gases (refer to the section on plastics in Chapter 15).

Petroleum products are called hydrocarbons because they are composed of hydrogen and carbon molecules. The arrangement of the molecules determines whether the product is gasoline, kerosene, heptane, or any of the many crude oil derivatives. When burning, these liquids give off a thick black smoke because of all the carbon they contain.

Whether the material burning is wood, plastic, paper, cloth, or oil, the products of combustion of these carbonaceous materials present a complexity of problems to the firefighting forces. Usually the combustion process is incomplete, resulting in the release of carbon and tar particles into the atmosphere, where they obscure visibility and irritate the eyes and respiratory passages. In addition, the toxicity of some of the gases presents a safety hazard, and, since some of the gases are flammable, there is the further hazard of their ignition when mixed with the right proportion of air. These problems are most acute at fires in structures. For that reason, and because most of our fire losses and fire deaths occur in buildings, let us analyze the progress of a fire in a building.

HEAT

A fire starts when some form of energy evolves sufficient heat to ignite a combustible surface. The fire's early progress depends upon the combustibility of that surface and the intensity of the heat. Some incipient fires will spread rapidly; others will smolder for hours.

There are three principal means by which heat can travel: convection, conduction, and radiation.

Convection

Convection is the movement of hot gases, which almost always move upward until they meet an obstruction and bank up there or move horizontally, still seeking to rise. This movement can be affected by wind and other air currents, even in a closed building (Figure 1.5).

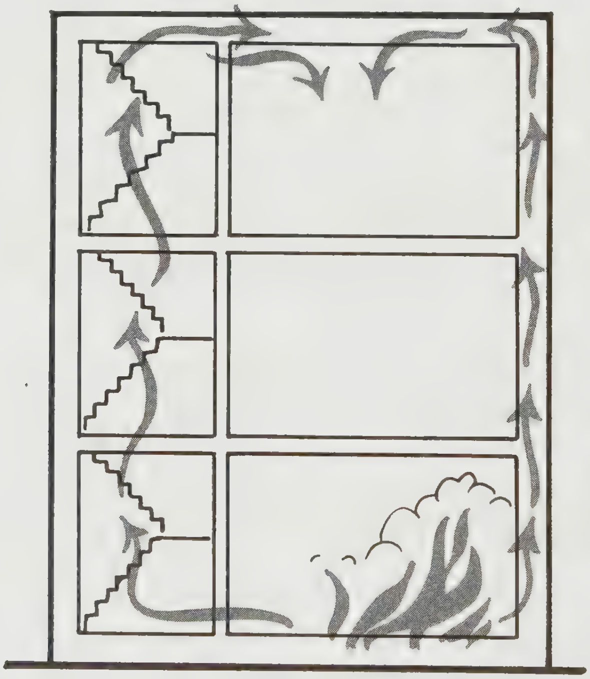


Figure 1.5. *Convection provides the most likely means of fire travel within a building, via wall spaces, stairway, and hanging ceiling (cockloft).*

Most fire travel within structures is by convection, both vertical and horizontal. The moving gases are usually hot enough to ignite combustible materials with which they come in contact near their source. The gases lose heat as they move farther from their source, but they can still ignite susceptible materials at surprising distances. Their tendency to move upward is the reason why the areas above a fire are the most vulnerable to the travel of hot gases and of the smoke that travels with them. The parts of buildings where the hot gases accumulate when upward travel is obstructed are the most dangerous from the standpoint both of ignition and of smoke (gas) inhalation.

Conduction

Another method of heat travel is *conduction*, which is not common at fires but can sometimes happen, with serious consequences. Conduction is the action by which heat is transferred through a solid, incombustible material. Sometimes heat is passed in this way through a wall or ceiling with enough intensity to ignite combustible materials touching the opposite side. Metals are excellent conductors of heat; brick and concrete are not. Yet there have been times when an intense fire of long duration has been conducted through a brick wall. Conduction through steel walls or ceilings, such as are found on ships, should be expected.

Radiation

A third method by which heat travels is *radiation*. Radiant heat is invisible. It travels in the same way as, and behaves very much as, light does, but it is of different wavelength. It emanates from the heat source in straight lines, equally in all directions, diminishing in intensity according to the square of the distance (inverse-square law) when emanating from a point source, but it diminishes in direct proportion to its distance from a line source. The total (perfect) radiation from a heat source is proportional to the fourth power of its Kelvin temperature; thus, if the Kelvin temperature is doubled, the radiated heat increases sixteenfold.

Radiation does not seem to be as great a contributor to fire travel within a building as convection is (although there is radiation downward from hot gases banked under the ceiling, and from flame traveling under the ceiling, either of which could ignite materials beneath). But radiant heat can be of great significance when considering the threat to relatively close external exposures (Figure 1.6).

Radiant heat is electromagnetic energy and does not become thermal energy until it excites the molecules of a substance by strikng

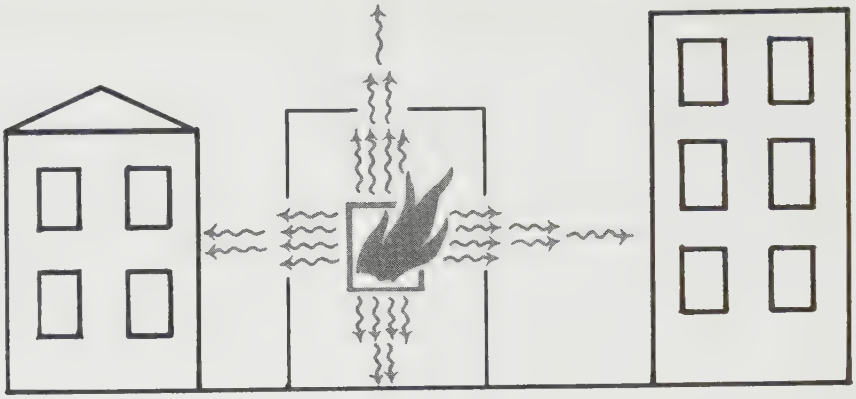


Figure 1.6. *The flame pushing out from the window in the center building radiates heat in all directions, regardless of the direction of the wind.*

that body. That is why water used to protect a surface exposed to radiant heat should be directed to strike and wet that exposed surface, protecting it by absorbing heat from it as fast as the heat is generated. Water should not be directed solely to form a "shield" between the radiant heat source and the exposed body. Radiant heat will travel through a so-called "water curtain" just as light does. Water absorbs thermal energy—not electromagnetic.

Some German experiments indicate, however, that there is partial attenuation of radiant heat by water curtains. Seekamp found that, with sprays of considerable density, the maximum decrement of radiant heat transmission was 22 percent. Schuler reported an absorption of 30 percent with dense curtains over a small opening. Practically, these findings mean a delay of 30 percent in the time to reach exposure ignition (six and one-half minutes instead of five). Still, a water curtain can arrest the flow of hot gases.

When we hear of how a fire will develop so many times a minute, we are dealing with fires that have reached a flaming stage. Then it would be normal for a fire to double in size about every half minute as long as there were sufficient fuel and oxygen. This process could continue until flashover is reached. (Doubling means that energy output, measured in watts, is doubled, not the area of the fire. If the area doubled twice a minute, it would increase from one to about two billion square feet in 30 minutes.) This type is called a fuel-controlled fire. Such fires can reach full development in a few minutes. Cases where the ventilation is inadequate for free burning are called ventilation- or air-controlled fires, because the curtailed availability of the oxygen controls the rate of burning. Fires of this type will fluctuate in intensity, breathing, so to speak, for a long period of time, as air is drawn in to the fire and then displaced with the products of combustion it helped to create. This intake and exhaust alternate until a steady state is reached, whereby air moves in along the bottom of whatever openings are present, and the exhaust moves out the top. This stage is soon followed by flashover, a phenomenon in which an interior fire suddenly increases greatly in size and intensity.

Some interior fires go through three stages: incipient, flaming, and smoldering. In the first two stages, there is sufficient oxygen, but the third is oxygen-starved. All fires do not go through distinct stages. Some go from flaming to smoldering to flaming several times, with the temperature rising and falling as the fire alternately consumes oxygen and then waits for more to reach it. Others will go directly to full development in a straight-line progression. The progress is governed by five major factors, which are:

1. The amount of exposed combustible surface (fuel source)
2. The arrangement of the combustible surfaces
3. The nature of the combustible surfaces
4. The ratio of combustible surface to room volume
5. The amount of ventilation

The total amount of combustible material is only of interest in determining how long the fire will burn if unchecked (Figure 1.7). The amount of surface is the fuel source that will determine the size and intensity of the fire. Only the portion of the combustible material near its surface is sufficiently heated to provide fuel vapors.

The arrangement of the various combustible surfaces within a building is an important factor. The floor can usually be discounted as a fuel source until after flashover occurs. On the other hand, a combustible ceiling will considerably decrease the time to flashover. The proximity of combustible objects to each other will influence the amount of radiant heat that they absorb. The arrangement of the surfaces also has a marked influence on heating by convection. A given amount of material stacked vertically will burn much more rapidly than if it were stored horizontally.

The nature of combustible surfaces will influence their ignition. Dark or rough surfaces absorb radiant heat faster than light-colored or smooth surfaces, and some materials have lower ignition temperatures than others.

DETERMINING FLASHOVER TIME

Assuming an adequate air supply (Figure 1.9), the ratio of combustible surface to room volume is the primary factor that determines time to flashover. A large amount of combustible surface will beget an early flashover. In some experiments, barn fires have reached flash-

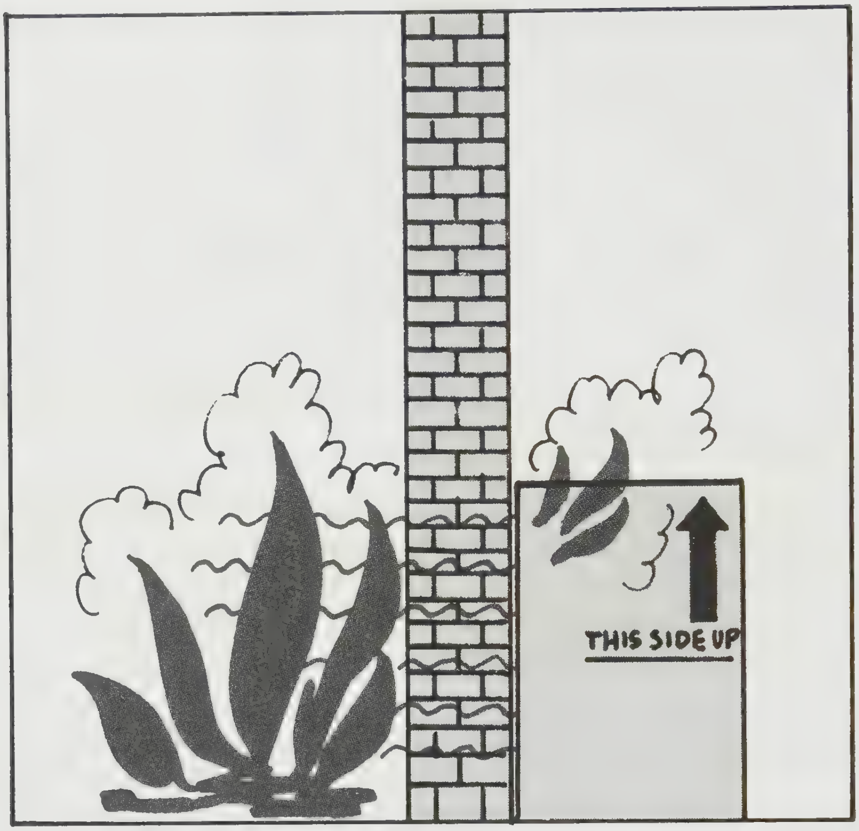


Figure 1.7. *Heat that is sufficient to ignite materials is rarely conducted through a reasonable thickness of brick or concrete, but it can happen in fires of long duration, and it must be guarded against.*

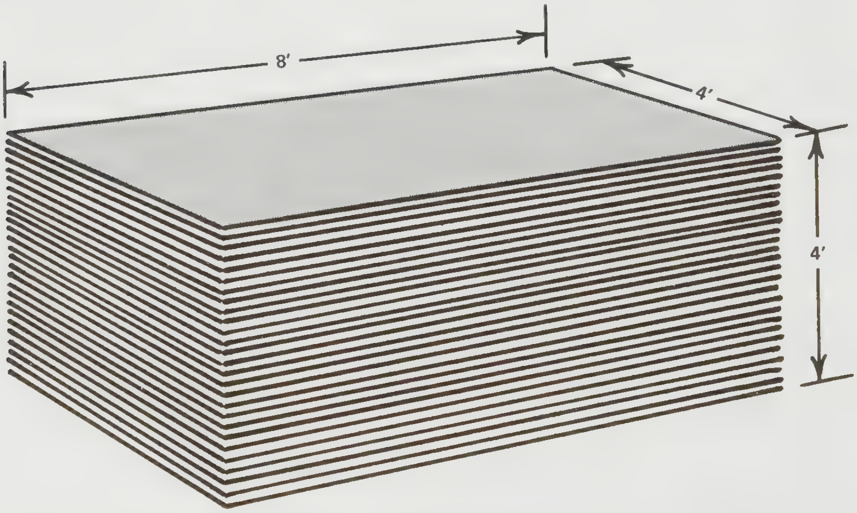


Figure 1.8. *The importance of surface: A pile of ½-inch plywood sheets that measure four by eight by four feet has an exposed surface area of 128 square feet. The sheets mounted separately (as on a wall) would have a surface area of more than 3,000 square feet.*

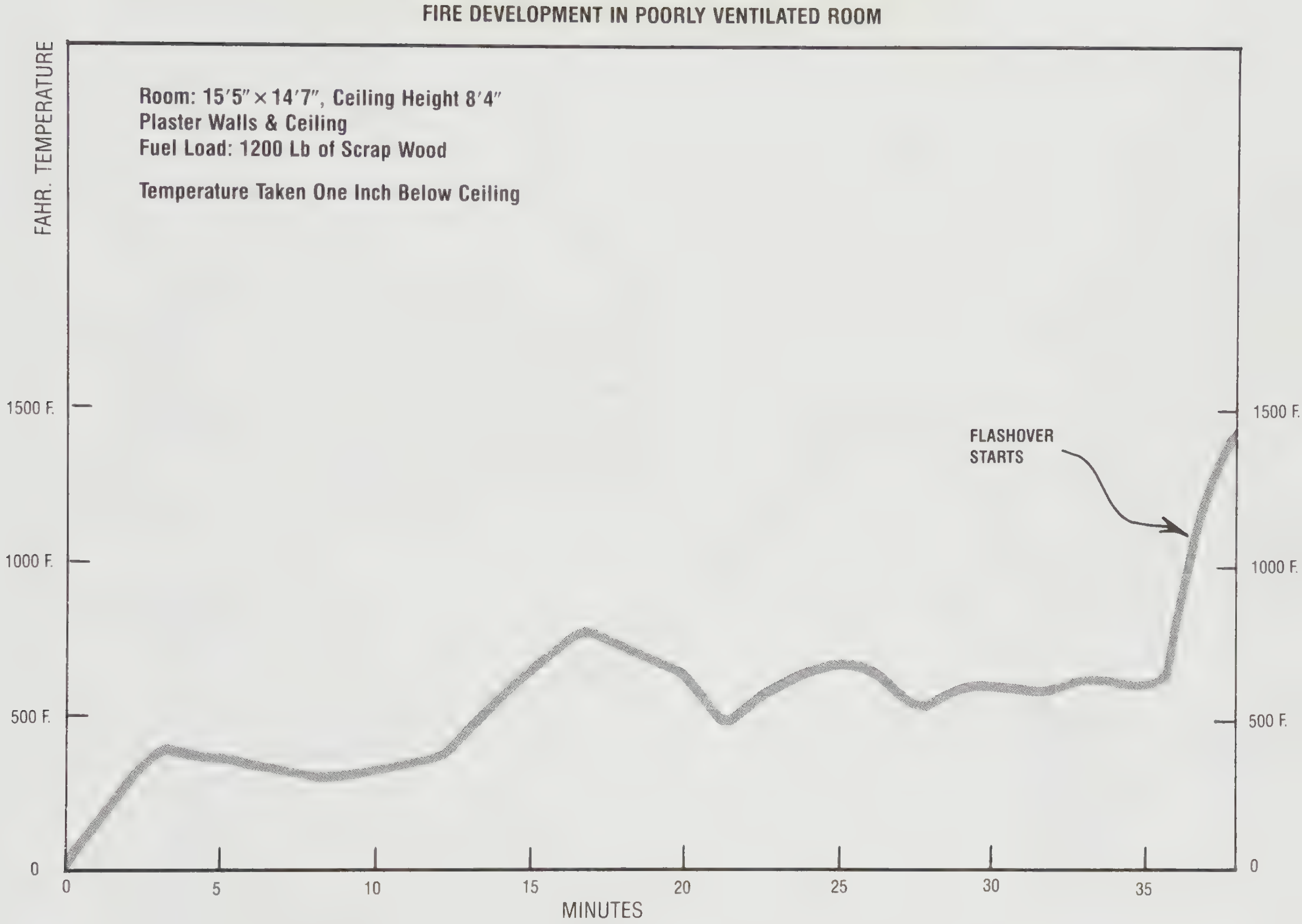


Figure 1.9. *Fire development in a poorly ventilated room.*

over just two minutes after ignition of stored hay. In ordinary dwelling rooms with plaster walls and ceiling and the usual contents, it took 30 minutes to reach flashover following the ignition of a bale of hay in a corner. Yet in a small enclosure such as a walk-in closet, fire reached flashover much more quickly, probably due to the fact that, in smaller rooms, both radiant and convected heat have less space in which to diminish before reaching combustible surfaces.

The rate of sustained combustion is largely determined by air flow. The amount of ventilation, therefore, can affect the progress of a fire either positively or negatively. An increased supply of oxygen can increase the speed of combustion. On the other hand, ventilation permits the escape of heat by convection; it can retard the progress of fire by releasing to the outside atmosphere much of the hot gases which, if confined, would hasten flashover.

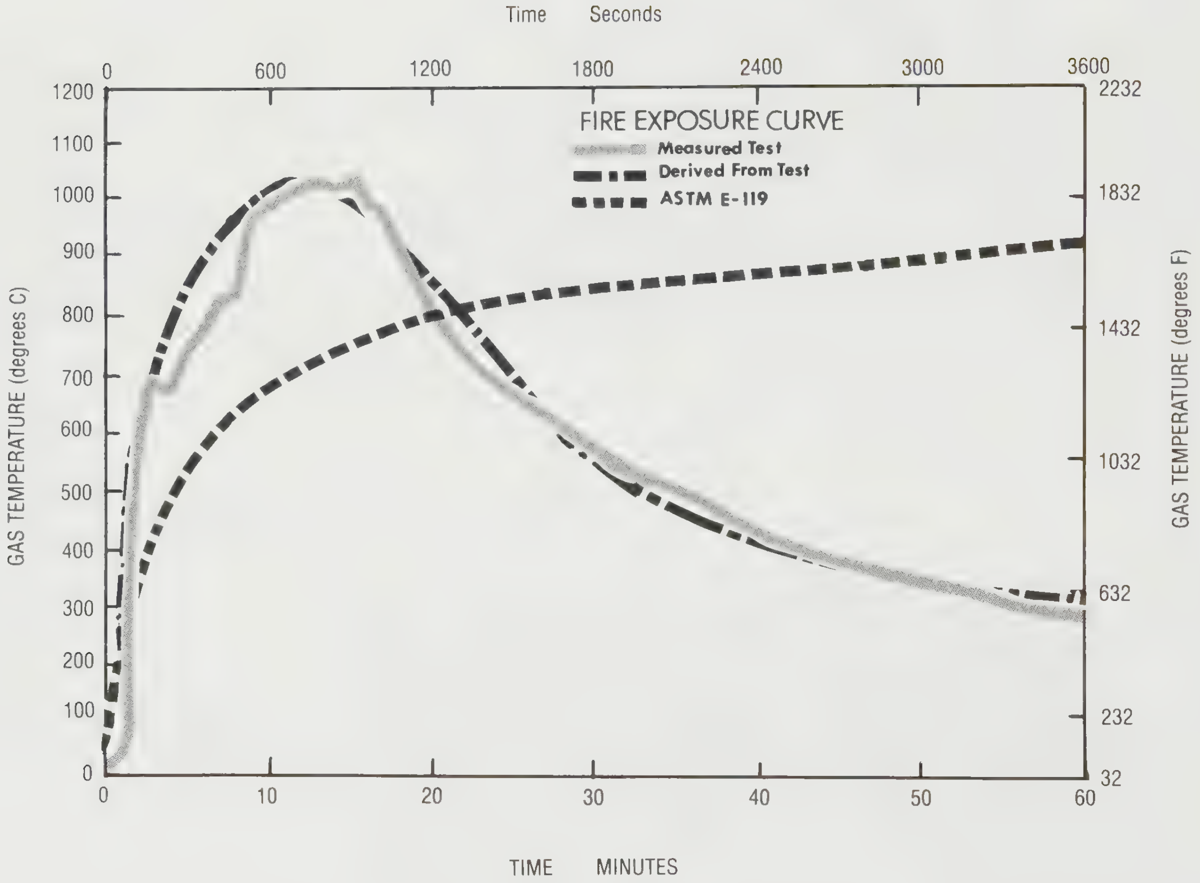


Figure 1.10. The A.S.T.M., E.119 fire test figures, also known as "standard time-temperature curve," derive from tests made early in the twentieth century. More recent tests with polymeric materials, instead of wood alone, show a different curve. In both series, fires were allowed to burn uncontrolled for an hour and obviously had adequate ventilation from the start. Room fires that are not well ventilated behave quite differently until flashover and then follow the "derived from test" curve above, if not attacked. See Figure 1.9.

If the ventilation to a fire provides an air flow sufficient to maintain steady burning, the intensity of a fire will increase in a straight-line progression. In a well-ventilated room, the fire will usually flash over in less than ten minutes, but in a poorly ventilated room the process will take much longer, even if it is the same room with the same fuel load.

If the air supply is limited, the fire's intensity will fluctuate in an undulating line, with both peaks and valleys gradually becoming higher until a temperature of about 800 degrees Fahrenheit is reached just below the ceiling. At that point, the temperature climbs rapidly to flashover, which almost always seems to occur at about 1,000 degrees Fahrenheit, measured at the ceiling. This fact has been evident in many of our experiments and is in agreement with the experiments of others.

Visual observation coinciding with temperature measurement shows that when the temperature of 800 degrees Fahrenheit is reached, the flame column is starting to impinge on the ceiling. As flame hits the ceiling, it starts to spread laterally along the under side of the ceiling, at a velocity of about six inches per second initially, but that speed increases in velocity as the flame extends, until flames shoot out the windows, and the room is what is commonly described as "fully involved" with flame.

FLASHOVER

This sudden full involvement is the phenomenon called "flashover," the critical point of fire progress. Most of our experimental fires have occurred in dwelling rooms with walls and ceilings of plaster on wood lath. Fires in these rooms usually take about half an hour to reach flashover when doors and windows are closed. The progress of the fire is usually slow and undulating until one minute before flashover, and in many cases the fire could be extinguished with a bucketful of water at that stage.

In that final minute, however, the fire's progress is remarkable. For instance, in one case we started a fire in the kitchen of a dwelling by igniting a bale of straw placed against a wooden cupboard at one end of the kitchen. The straw burned rapidly, igniting the cupboard, which continued to burn slowly after the straw had been consumed. Thirty minutes after ignition, a paper window shade on the opposite side of the room was still intact, but at 31 minutes, flames were shooting from all the windows and were extending rapidly throughout the building.

If firefighters arrive before flashover, they will find a low-intensity fire which requires little water for extinguishment. If they arrive a moment after flashover, they will be confronted with a high-intensity, fast-spreading fire. Relatively few firefighters have actually seen flashover take place. If they arrive in time, they prevent it from happening. If they arrive after it happens, they miss seeing it occur.

My own experience has been mostly with training and experimental fires in buildings scheduled for demolition. Even though I have witnessed well over a hundred flashovers in real buildings rather than laboratory models, I am hesitant to take a firm position on what flashover is and what causes it. Because I have seen so many fires progress from ignition to flashover in our own experiments, I know how capriciously fire can behave and how difficult it is to define what is actually taking place.

I am inclined to believe that hot gases play a greater part than radiation. Consider, for instance, a fire burning in a fireplace. It radiates heat into the room, but the hot gases go up the chimney. The radiation doesn't ignite objects in the room. If the same fire were on the floor in the middle of the room, it would lead to flashover. Its hot gases would not be escaping up the chimney but would be accumulating under the ceiling. We once experimented by having a smoke ejector pull the smoke and gases out a window as a large chair burned. It vigorously burned to ashes without igniting a couch only two feet away.

In another test, we obtained flashover by burning a wood test crib on a slide, so arranged that the crib was pulled out of the room through a window when flashover took place. One minute after the crib hit the ground, there was no more fire in the room that had just been fully involved. The crib had been the only combustible object in the room and it had reached its ignition temperature long before the flashover. The flashover must have been the burning of gases given off by the crib.

In our observations of the progress of these experimental fires, it appeared that convection of hot gases is responsible for most fire spread. This impression, coupled with the fact that flashover usually occurs at or near the ignition temperature of carbon monoxide, seems to indicate that flashover may be the ignition of a gas layer under the ceiling. If the hot gases are removed by ventilation or cooled by water, flashover is retarded.

There is a school of thought which maintains that flashover is not the ignition of a gas layer under the ceiling, but rather is the sudden ignition of all combustible objects in the room when they reach their ignition temperatures simultaneously; this theory suggests that the heat radiated from walls and ceiling causes all these materials to heat up to that point.

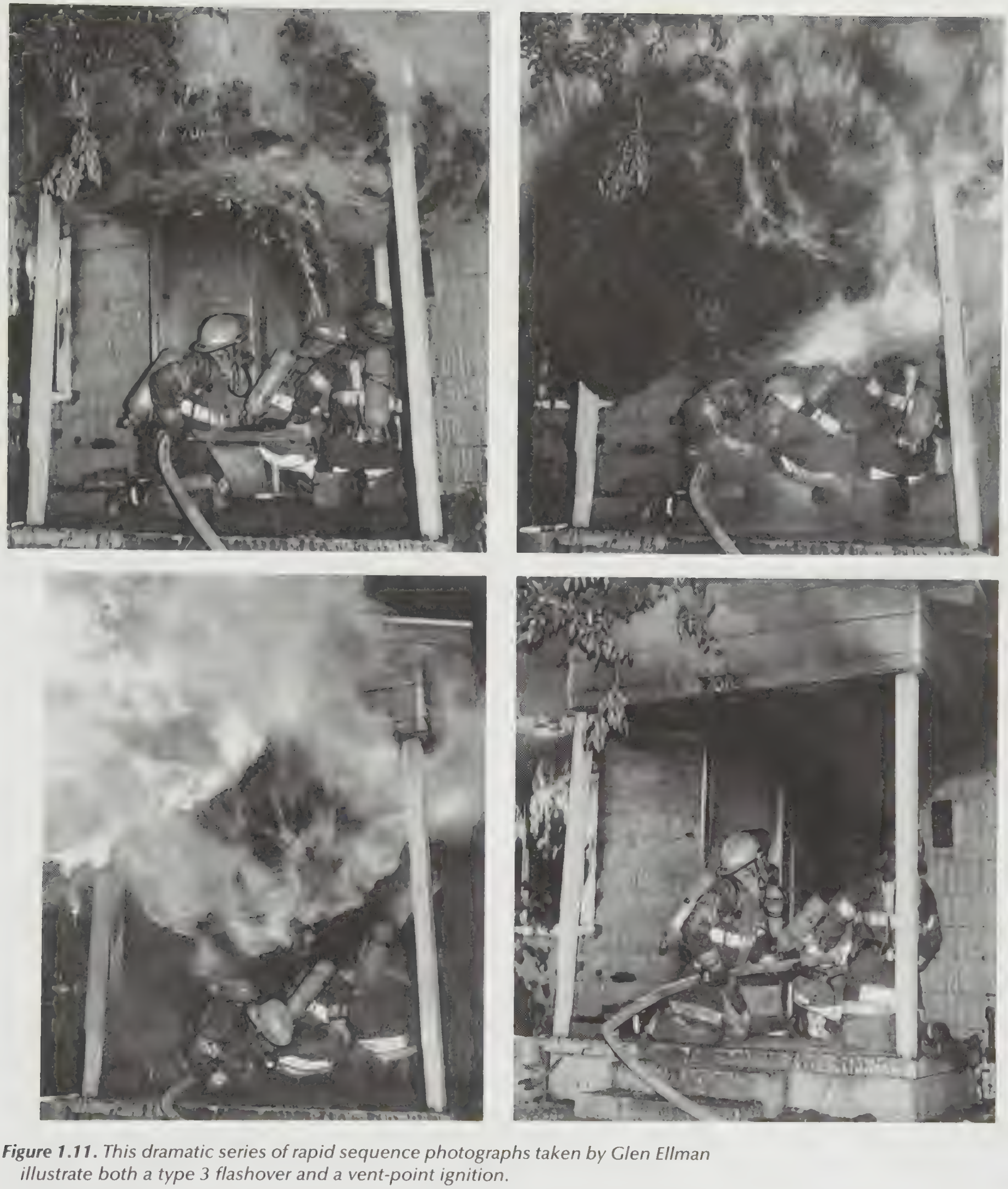


Figure 1.11. *This dramatic series of rapid sequence photographs taken by Glen Ellman illustrate both a type 3 flashover and a vent-point ignition.*

A. Flame darts out the left side of the doorway, while a small cloud of thick black smoke containing hot gases, too rich to burn, appears on the right.

B. The cloud on the right ignites when mixed with air, and another black cloud appears suddenly on the left.

C. The black cloud on the left ignites vigorously.

D. The flashover has subsided. No one was hurt: the protective clothing did what it was designed to do—it gave adequate protection for a very brief exposure to flashover temperature. (Refer to Chapter 8 on safety for further information.) The short duration of the flashover is indicated by the still legible house number, unscathed porch columns, and leaves on the tree. The house, unoccupied, had no contents, and tests after the fire found no trace of flammable liquid.

It is highly likely that, in current arguments, the term "flashover" is being applied to what are actually several different processes.

One of these would occur when a fire with a continuous supply of oxygen proceeds directly to full development in a straight-line, extremely rapid progression. Let us call this a Type 1 flashover.

A second would happen when flame ignites unburned fire gases that have accumulated near the ceiling (Type 2 flashover).

A third would take place when the gaseous products of both pyrolysis and combustion, initially too rich a mixture to burn, suddenly obtain enough oxygen to make a combustible mixture, which ignites vigorously (Figure 1.11). In some cases the major products are derived from pyrolysis; in others, they are from incomplete combustion; and in still other cases, from both (Type 3 flashover). In my opinion, this third type is what happened in the Kings Cross station of the London underground railway, killing 31 people, including a firefighter, when the gases reached the lobby.

A fourth type would occur when there is a sudden change in the composition of the accumulated gases in the room. The fire gives off large amounts of carbon dioxide, which is not combustible, but when the temperature of this gas is raised over 1,200° F, it will break down to form carbon monoxide. At that same temperature, the large amounts of water vapor given off by the fire will also unite with carbon to form hydrogen and more carbon monoxide. The gases change as follows:

$$C + CO_2 \rightarrow 2CO \qquad [1]$$

$$C + H_2O \rightarrow CO + H_2 \qquad [2]$$

A large quantity of non-combustible gases, which had been slowing combustion, is suddenly transformed into copious amounts of two highly combustible gases, which ignite. We shall call this a Type 4 flashover but point out that it may follow any of the other types.

I am hesitant to speculate on a fifth type of flashover and would not discuss it or believe it if I hadn't seen it happen. It takes place when a fire no bigger than a man's hand goes to flashover of an entire room in less than one minute, with no fuel sources other than ordinary furniture. Our knowledge of flashover is woefully incomplete; perhaps it should be examined for submolecular causes (Figure 1.12).

An additional hazard is the traveling flashover (Figure 1.13). The rapidly expanding gases from a room that has flashed over can race through a hallway and even up a stairway with great speed and fatal effect, spreading fire as the gases ignite at distant locations where there is sufficient air.

What does all this mean to the firefighter in a practical sense? It means much that would affect his or her survival. Many firefighters

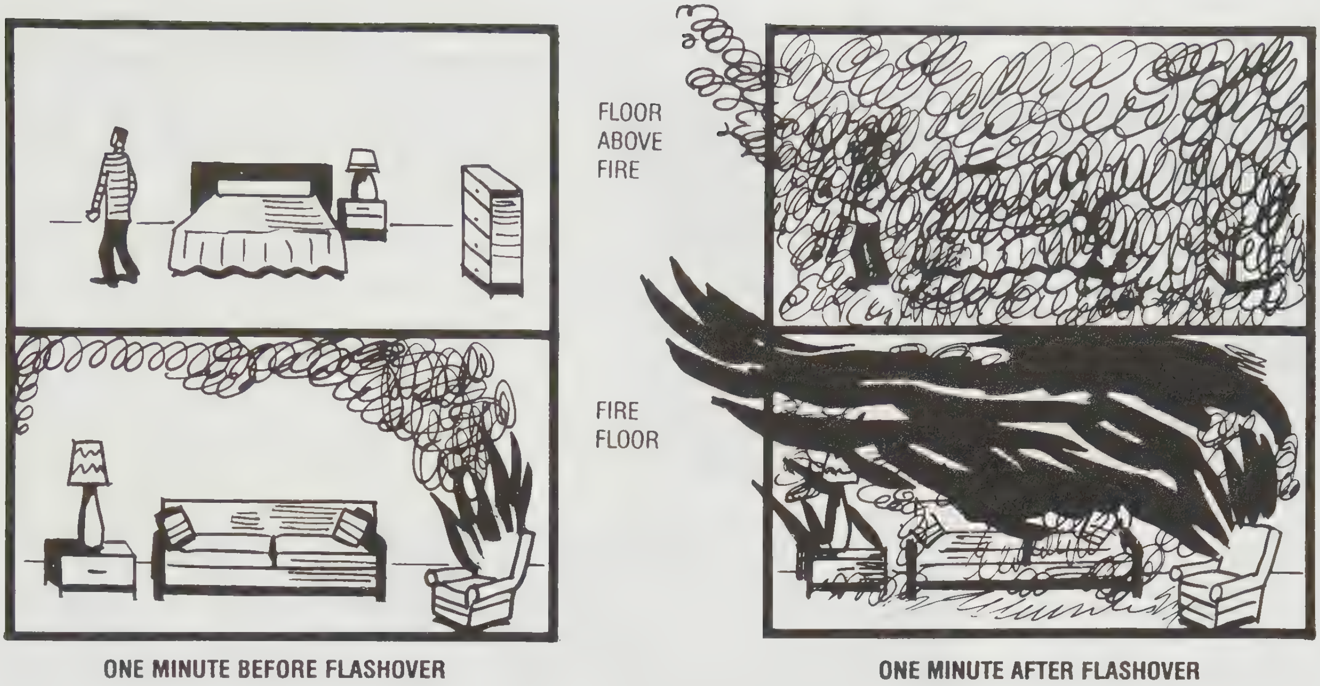

FLOOR
ABOVE
FIRE
FIRE
FLOOR
ONE MINUTE BEFORE FLASHOVER
ONE MINUTE AFTER FLASHOVER

Figure 1.12. *How fire progresses at flashover.*

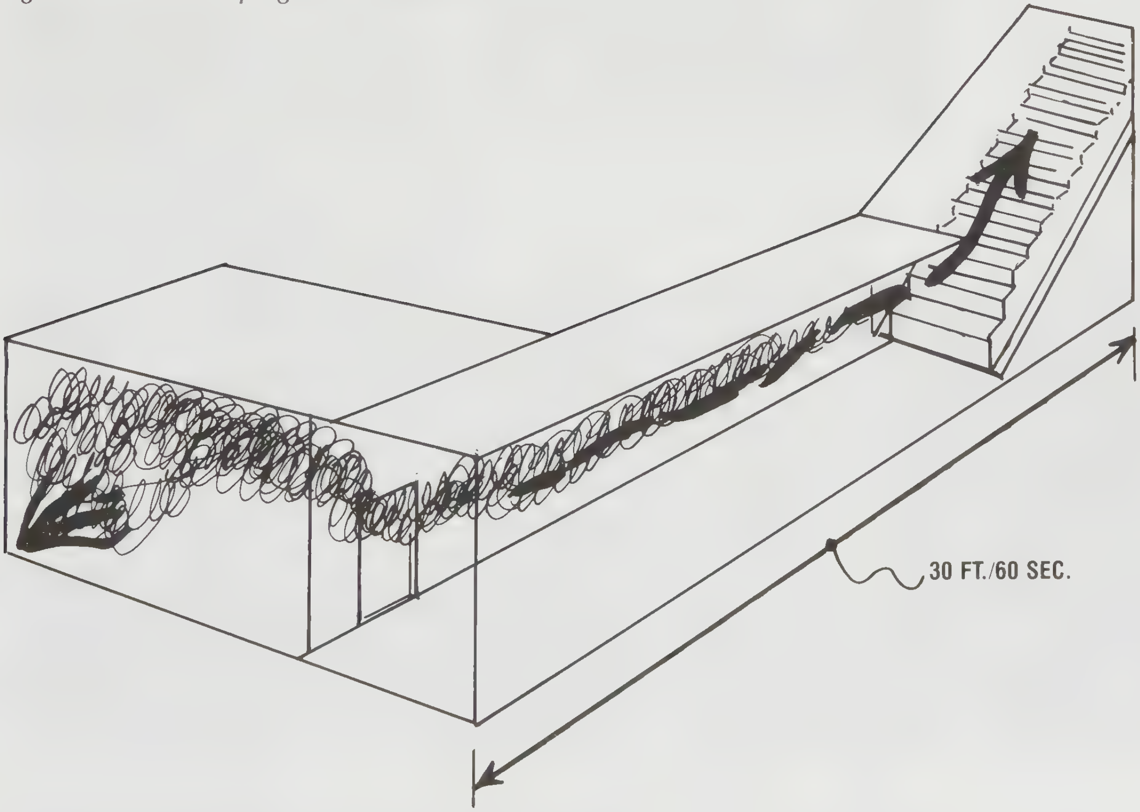
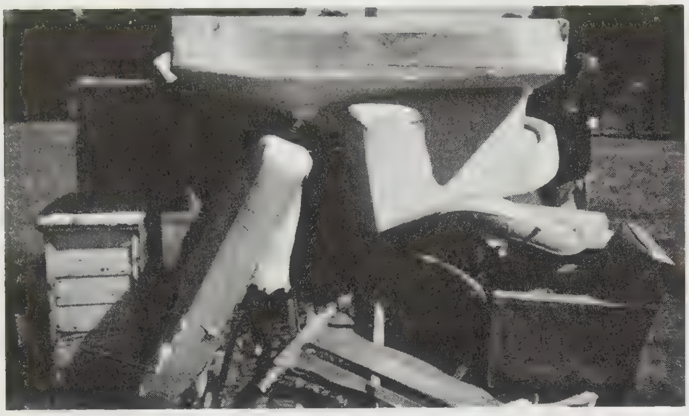
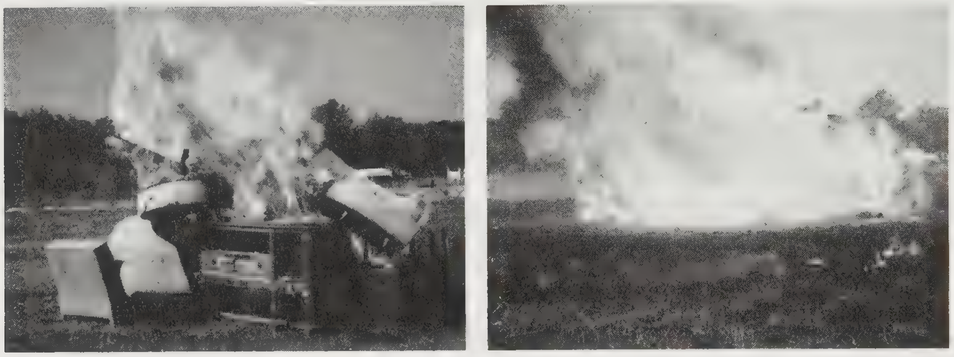


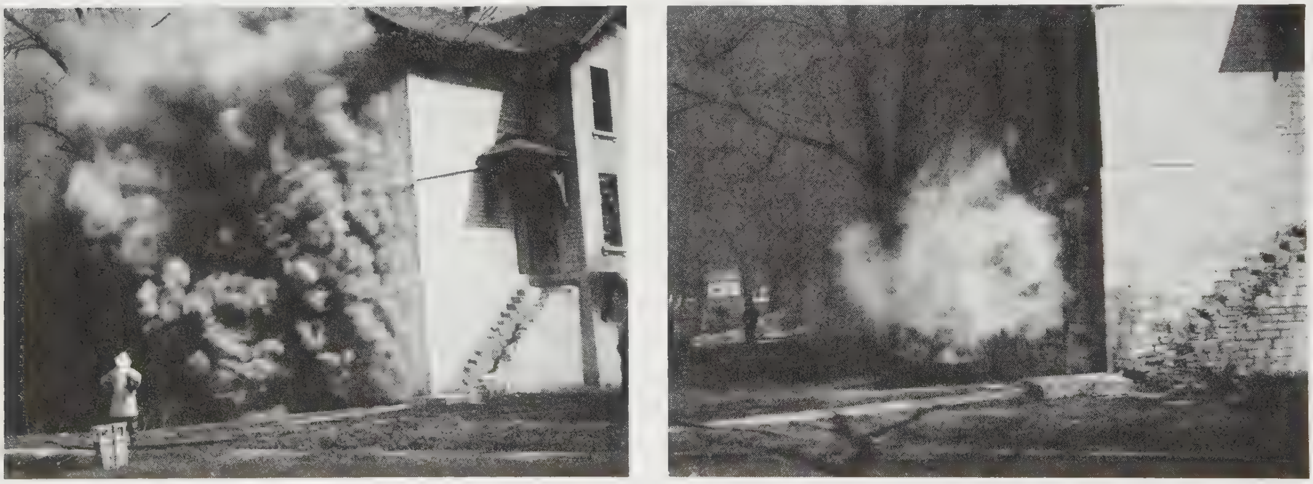
Figure 1.13. *Traveling flashover. Fire in the room at the left generates a gas mixture which is too rich to burn until it migrates into the hall, where it finds enough oxygen and ignites. The burning gases travel along the hall and up the stairway.*

Figure 1.14. A. *The contents of a small apartment are assembled in an open field and ignited by lighting a newspaper.*





B. *This photograph was taken three minutes after ignition.*
C. *This photograph was taken three minutes after that shown in B. The effect of an unlimited air supply is a rapid build-up and a clean-burning fire.*



D. and E. *The same amount of furniture is crammed into one large room and ignited. Lack of ventilation limits the air supply, slowing the fire and generating much smoke, but after it is ventilated the fire is easy to find and fight. The sudden increase in fire intensity shows, however, the need for keeping charged hose lines ready when the ventilation begins.*

have been killed or severely injured by flashover. On the other hand, some have been saved because they recognized the symptoms preceding flashover and escaped in time. Others were saved because they anticipated flashover and took precautions to prevent it.

The insidious aspect of flashover is its sudden onset. It doesn't allow much time for action, let alone deliberation. In both small rooms and large, firefighters have been badly burned when a moderate fire situation suddenly turned to full involvement of the room. In some instances, firefighters have been forced to jump from windows. A fire company had to jump into the water from a pier because the fire was traveling through the pier shed faster than they could run. Flashover has been considered in the design of protective clothing, but present standards require only fifteen seconds' protection against flashover temperatures, just enough for a quick retreat to a readily available exit.

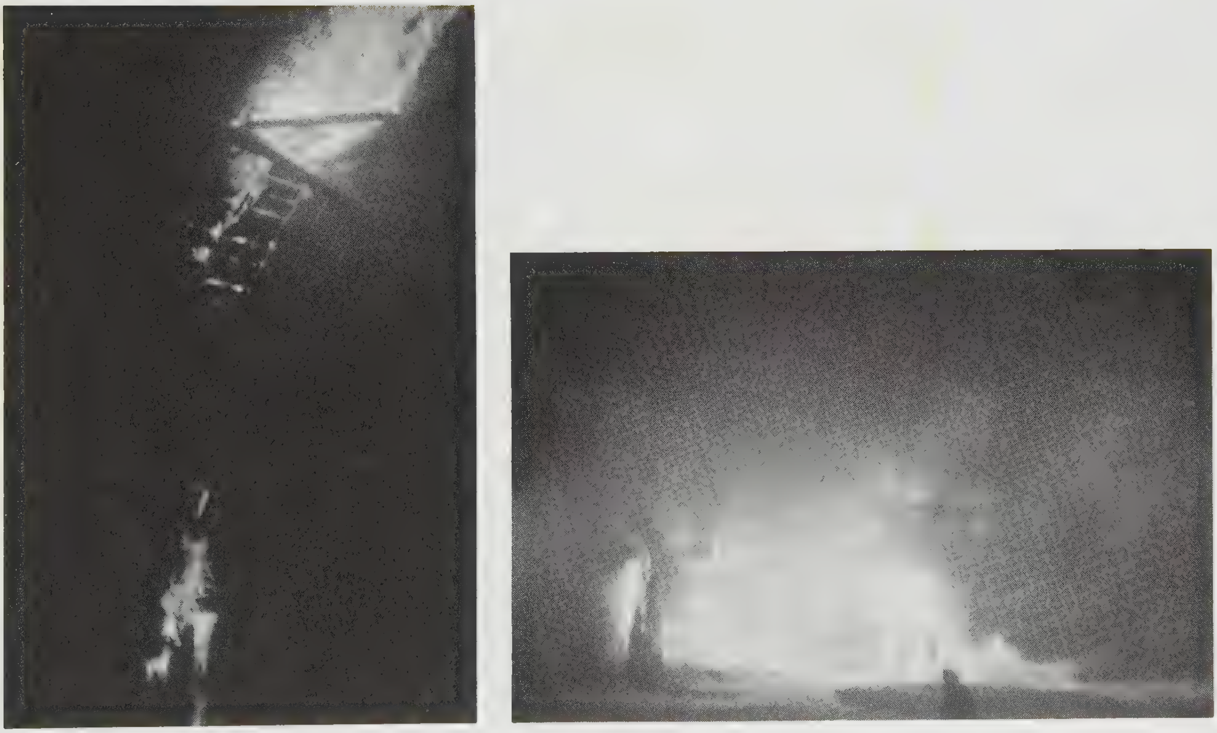


Figure 1.15. A. *Flashover can occur suddenly. This picture was taken inside an empty all-wooden barn.*
B. *This picture of the same barn was taken from the outside less than one minute later.*

Probably the best way to protect against flashover is to keep it in mind, remaining alert for the chance of it happening and taking precautions where warranted. Years ago, I was shocked to see a Manhattan engine company open the nozzle in the doorway of a loft and direct their stream to cool all the ceiling that could be reached, before moving in to find and attack the fire. Then I discovered that they knew from experience that the fire was of a type that might suddenly move into the flashover stage. Cooling the ceiling was also resorted to when there was heavy involvement of a store basement with an open stairway to the store. Here, even though there was as yet no fire in the store, the store ceiling was cooled with hose streams to prevent flashover in the store as a result of hot gases ascending the stairway.

Perhaps the only reliable warning that flashover is about to take place is a sudden, unaccountable increase in temperature. Heavy smoke is not always present, and the visible increase in the fire doesn't occur until after the sudden increase in temperature has been felt. Therefore, an unaccounted-for increase in temperature should be taken as a warning that flashover will follow. If, at the same time, flames are reaching the ceiling, it is a double warning, and time is short.

Full protective clothing and breathing apparatus offer some hope of survival, but may, on the other hand, prevent the sudden increase in temperature from being noticed. Also, breathing apparatus is allowing firefighters to get into dangerous situations farther from exits than they would proceed without its assistance.

Remember that cooling the ceiling may prevent a flashover in the room that is being cooled, but, if the fire is in an adjoining room, such cooling will not prevent flashover from happening in that room.

Because most experiments have been made in laboratories or single-story structures, little has been written about what happens in the room directly above that in which the flashover occurs. I have observed it go from no smoke at all to a room full of hot smoke in a matter of seconds. Such an event caused several deaths in a second-floor restaurant in Manhattan. Therefore, the floor above the fire should be kept in mind when considering flashover (see Figure 1.12).

There is another phenomenon, somewhat akin to flashover but not identical which occurs when some of the combustible vapors from the fuel source can't get enough oxygen to burn (the mixture is too rich). Yet the vapors are hot enough to ignite. They travel to an opening where they mix with enough oxygen for combustion, and suddenly they ignite. This phenomenon occurs at windows and doorways, and sometimes in halls and on stairs. The precursor of such ignition is the appearance of thick black smoke. Once this ignition takes place, the fire seems to get enough oxygen to assume a steady state of rapid burning without repetition of the black smoke ignition. When smoke coming through an opening is thick and black, with sooty carbon particles, a sudden burst of flame may soon follow it, and firefighters standing too close may get burned. This process could be termed "vent-point ignition."

BACKDRAFT

What has been commonly named backdraft for many years is also called "blowback" and "smoke explosion." All are terms for the same process and are not meant to differentiate. The phenomenon concerned, however, which we will call backdraft, may be the result of different mechanisms.

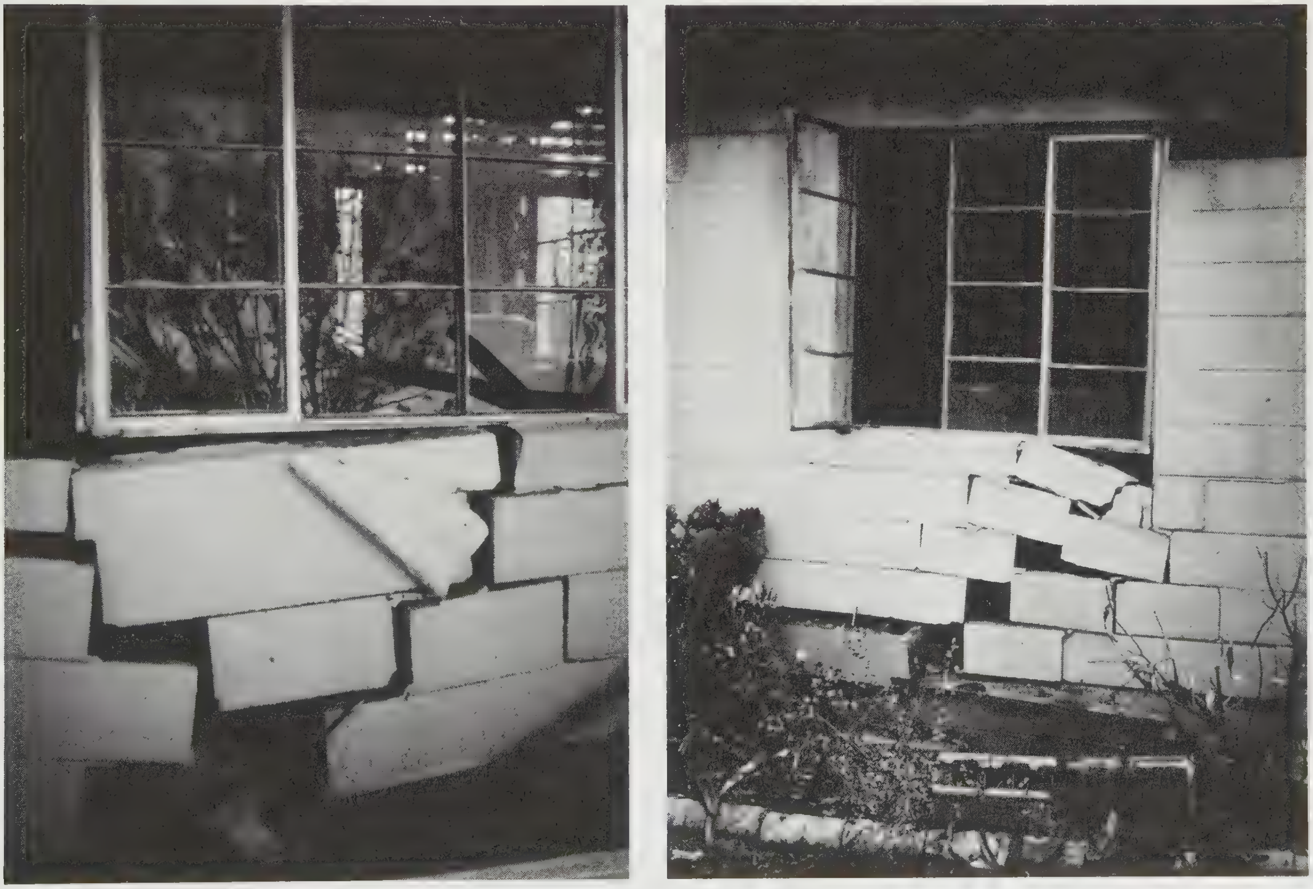


Figure 1.16. A. and B. *Backdraft can exert enough physical force to cause significant structural damage. These photographs show a one-story dwelling. Note that window glass is still intact. The explosion was probably a type 3 backdraft in the crawl space; it pushed the course of blocks at floor level outward seven inches, which caused the blocks above to drop.*

Type 1 Backdraft

It has been generally agreed for a long time that backdraft occurs when an oxygen-starved fire in an enclosure suddenly gets enough oxygen under conditions that will beget an explosion. The classic example (which we will call a Type 1 backdraft), occurs at a fire so lacking in ventilation that a large amount of unburned gases accumulates during lengthy smoldering. Then, with the admission of air, the gases form an explosive mixture with the oxygen in the air. If the gases are hot enough, the gas-air mixture will ignite when the right proportion is reached, and rapid ignition will occur with sufficient force to be considered an explosion; the force derives from the rapid expansion of the gases. As they increase in temperature, they exert pressure because they are contained (Charles' Law). This pressure may be sufficient to perform work and, by that definition, constitutes an explosion. The work performed may range from blowing firefighters off their feet to pushing out the wall of a building. Although by this definition it is an explosion, a backdraft is really a deflagration, and, although it is very rapid combustion, the shock wave rarely exceeds the speed of sound; there is not the detonation associated with higher types of explosion.

The type of backdraft just described sometimes occurs when firefighters make entry into a building where a fire has been smoldering for a considerable period of time. Their entrance allows air to enter and mix with the hot gases, and the explosion follows a moment after the opening has been made. The process is believed to be as follows.

Incomplete combustion during the smoldering stage produces large amounts of carbon monoxide (CO) because there is insufficient oxygen to generate carbon dioxide.

$$\text{Normal combustion: } C + O_2 \rightarrow CO_2$$

$$\text{Incomplete combustion: } 2C + O \rightarrow 2CO$$

CO_2 will not burn, but CO is quite combustible and will burn rapidly when mixed with oxygen. It has a lower explosive limit of 12 percent, but that limit was derived in tests at room temperature. The real limit is much lower at the high temperatures encountered at fires. A mixture of CO and oxygen will ignite at 1,100° Fahrenheit, which is commonly exceeded at the ceiling of a room where a fire has been burning. It is also probable that lesser amounts of methane may be present and ignite. Carbon and tar particles will be present to burn, too, and in fact they will probably ignite before the CO, because of their lower ignition temperatures.

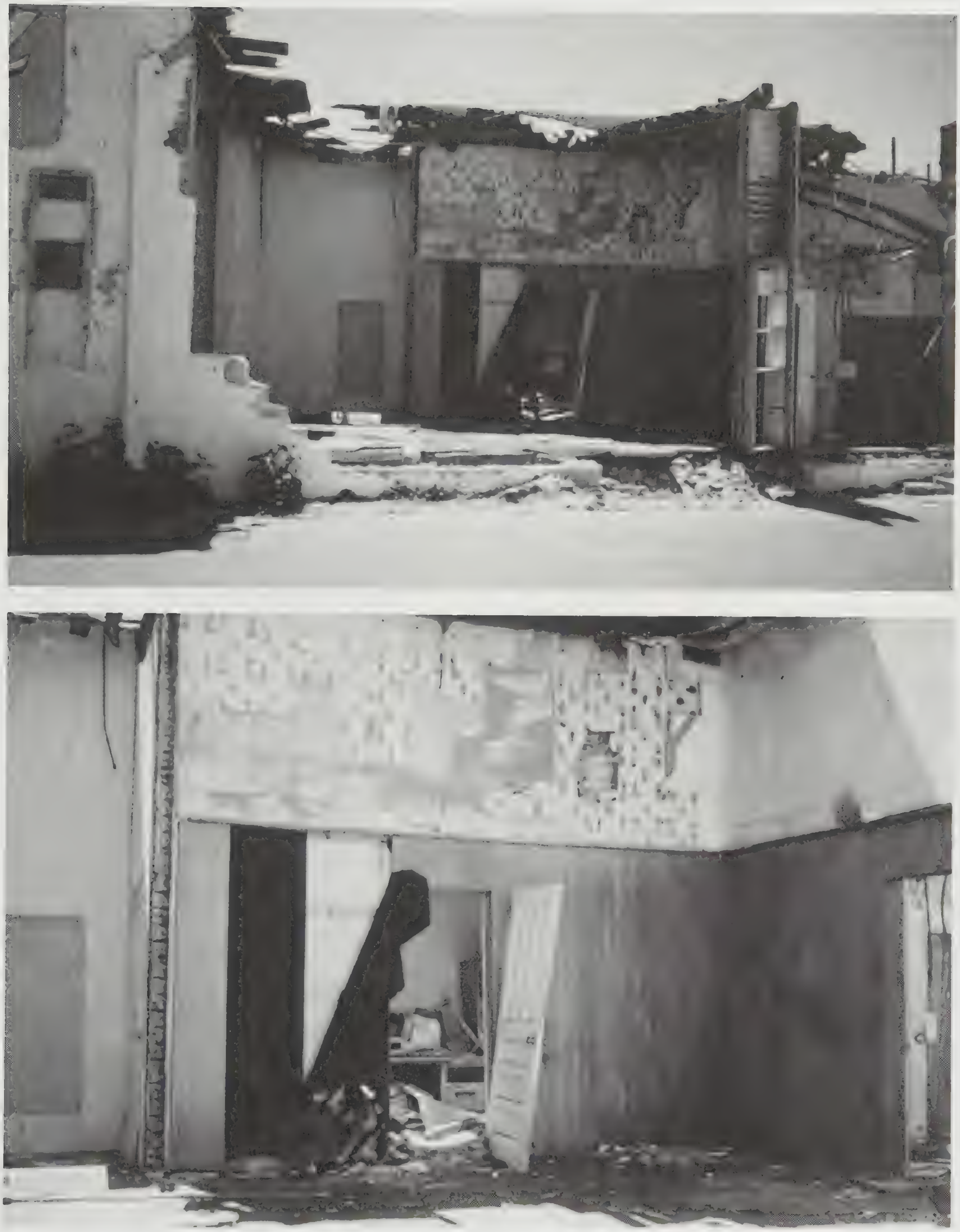


Figure 1.17. A. and B. *Although forceful, this backdraft did little heat damage. The force pushed out a concrete block wall, but the flash was of such short duration that the room shown in B. was not even scorched.*

Type 2 Backdraft

Some firefighters have been puzzled by the fact that they have encountered a backdraft at a fire which was not smoldering, but which had flame showing. This condition may occur because backdraft can also result from an explosion of CO created by a different process. In this case, the fire burns with sufficient oxygen to make CO_2 and also H_2O (steam). At high temperatures (1,200° Fahrenheit or higher), there can be two new gas reactions in the presence of incandescent carbon, in the form of yellow flame or free smoke particles. These reactions are:

$$C + CO_2 \rightarrow 2CO \qquad [1]$$

$$C + H_2O \rightarrow CO + H_2 \qquad [2]$$

The products of these reactions are double the volume of the gases to the left of the arrow. Two volumes of CO are derived from one of CO_2, and one volume of CO and one of H are derived from one volume of steam. What we then have is the rather large production of carbon monoxide (CO) and hydrogen (H), both of which are flammable gases.

This process was used commercially years ago to produce illuminating and heating gas. Steam was forced through burning coke to create the reactions; thus it was called the water gas method.

Type 3 Backdraft

Another type of backdraft can occur when sufficient oxygen is already present and mixed with gases and unburned carbon and tar particles, but the mixture is not hot enough. Then, suddenly, hotter gases or flame enter the area and cause ignition.

Precautions

Naturally the question arises as to how these conditions can be anticipated and either prevented or controlled to cause minimal harm. Several steps can be taken.

The first is recognizing a condition likely to lead to backdraft, such as indicators that a fire has been burning with a limited air supply for some time. These indicators include:

1. The fire is in a commercial occupancy which has been closed for several hours. (If we had a fire in a factory on a Sunday, we would expect a backdraft.)

2. The windows and doors are closed, but smoke is seeping out around them.
3. The smoke rises rapidly close to the wall, indicating that it is hot.
4. Window glass is discolored and may be cracked from heat.
5. Little or no flame is visible.

This situation is the classic case in which the admission of air may trigger the backdraft. When a door is opened, air is sucked in, sometimes noticeably because smoke is pulled back with it.

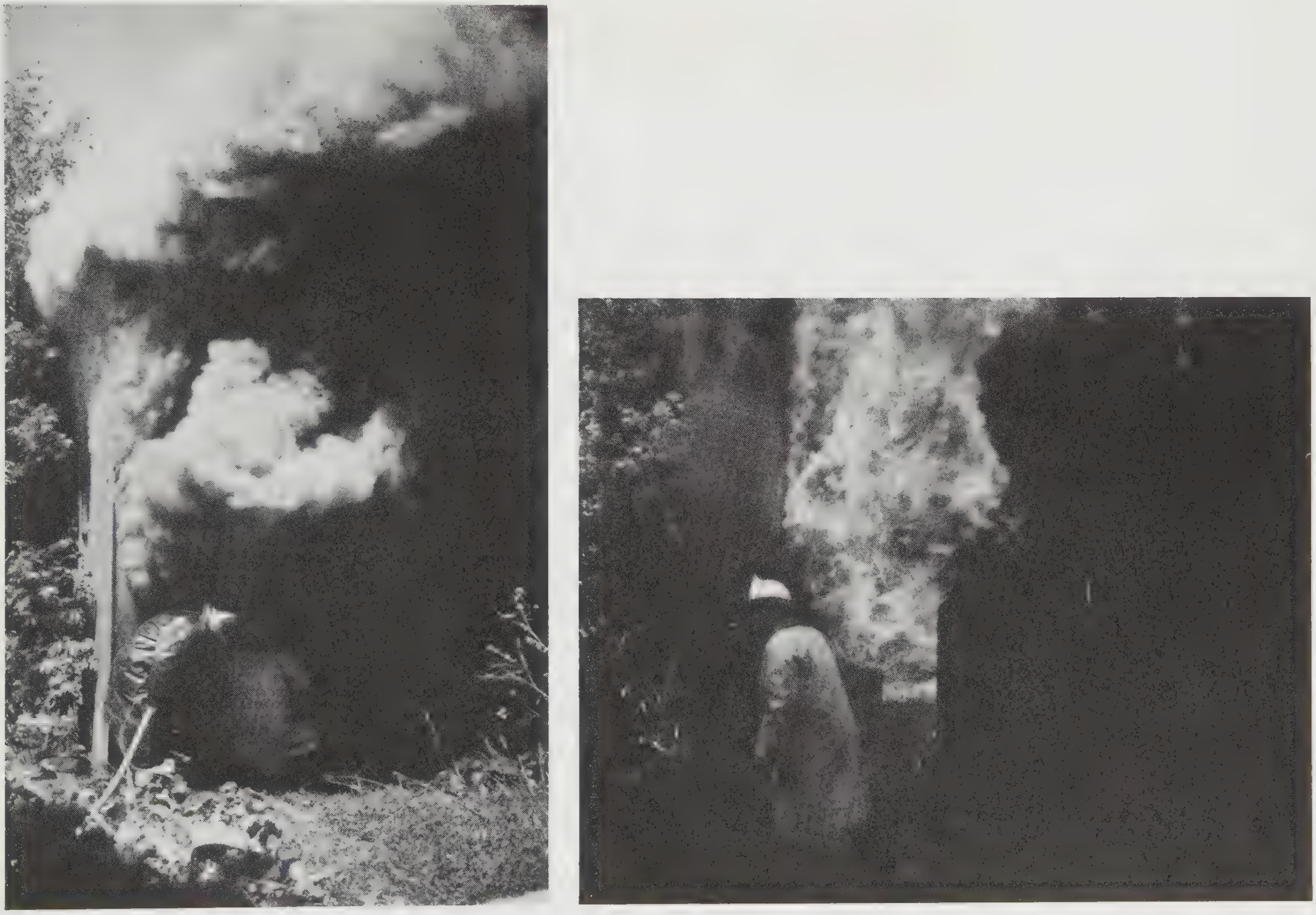


Figure 1.18. *Vent-point ignition can occur when fire gases too rich to burn inside a structure ignite when they mix with outside air at a door, window, or roof opening. The emission of thick dark smoke is a warning that flame may follow quickly and sometimes violently.*

Unfortunately, the force of the backdraft, a moment later, is usually great through the doorway, and people in its way will be hit by it.

Ventilating elsewhere before opening the door is a reasonable precaution. If the ventilation opening is high enough, such as at the roof when the fire is on the story below the roof, it may allow the escape of combustible gases before these ignite, or, if they do ignite, such ventilation makes the explosion less dangerous. If roof ventilation is not suitable, windows can be opened, and personnel may stay clear for a minute before opening the door. Remember that a wall can be blown down by backdraft and cause serious injury to those nearby.

If it is possible to cool the ceiling in the fire area safely with a water stream, this action will lessen the chance of both backdraft and flashover.

Nevertheless, there have been cases where backdraft occurred for no apparent reason in buildings where the fire was free-burning and had burned through the roof. It is likely that gases accumulated in a part of the building separated from the fire, such as a void created by a double roof or double floor.

In some cases, more than one backdraft occurred at the same fire. One of these buildings had a double roof; another had a double floor. It may be that gases too rich to burn accumulated in such a space and, as they cooled, they contracted, allowing air to enter although the gases were still hot enough to ignite.

Backdraft rarely occurs in single-family dwellings, but it can sometimes happen—one did in St. Petersburg, Florida, in 1984—with considerable force. It blew firefighters from the porch into the yard and pushed a wall out seven inches. Oddly, it didn't break the window glass. This case was apparently a Type 3 backdraft, which led St. Petersburg chief Jerry Knight to call it a "cold smoke explosion," a very suitable term.

Just as in the case of flashover, there is still much to be learned about backdraft. Remember that there is a backdraft triangle, just as there is a fire triangle, and if the oxygen, fuel vapors, and temperature can be kept from mixing in the right amount, the backdraft may be prevented. If it can't be prevented, at least its harmful effects can be limited if proper precautions are taken.

2

The Mechanisms of Fire Extinguishment

THERE ARE several ways in which fire can be extinguished and several substances, called "extinguishing agents," which can be effective in putting out fires; the most popular of these is water. Water has the ability to absorb more heat than other readily available substances; it is also abundant. For these reasons, it has long been man's principal means of extinguishing fire. Sometimes other reasons are given; namely, that it is cheap and is easy to obtain and apply—which is not entirely true. It is a premise we have accepted through custom, but, if we analyze the facts, it becomes apparent that the process of extinguishing fire by water is cumbersome and generally costly.

Such analysis would show that the cost of installing water mains large enought for required fire flow, the installation and maintenance of hydrants, and the acquisition and maintenance of fire department pumpers, hose, and nozzles, make water a fairly expensive extinguishing agent.

For example, a community with a population of 2,000 experiencing a normal number of fires, and with a municipal water supply and fire department of approved strength, would find that the cost of water is in the neighborhood of $5,000 per structural fire, or more than $10 per gallon of water used.

Water, too, is not always easy to obtain. In rural areas, water supplies are often too far from the fire to be of any use, and, even in large cities, there are frequently problems in obtaining water in sufficient quantity for a large fire and in delivering it to the fire. Then there is the problem of applying the water.

Getting the water to the nozzle in sufficient quantity and pressure is only part of the need. The most difficult part is getting the water on all of the fire. In many cases, this action is impossible due to smoke, heat, structural weakness, and concealed fire. For these reasons, thousands of buildings are destroyed yearly in the presence of a firefighting force with sufficient water and equipment.

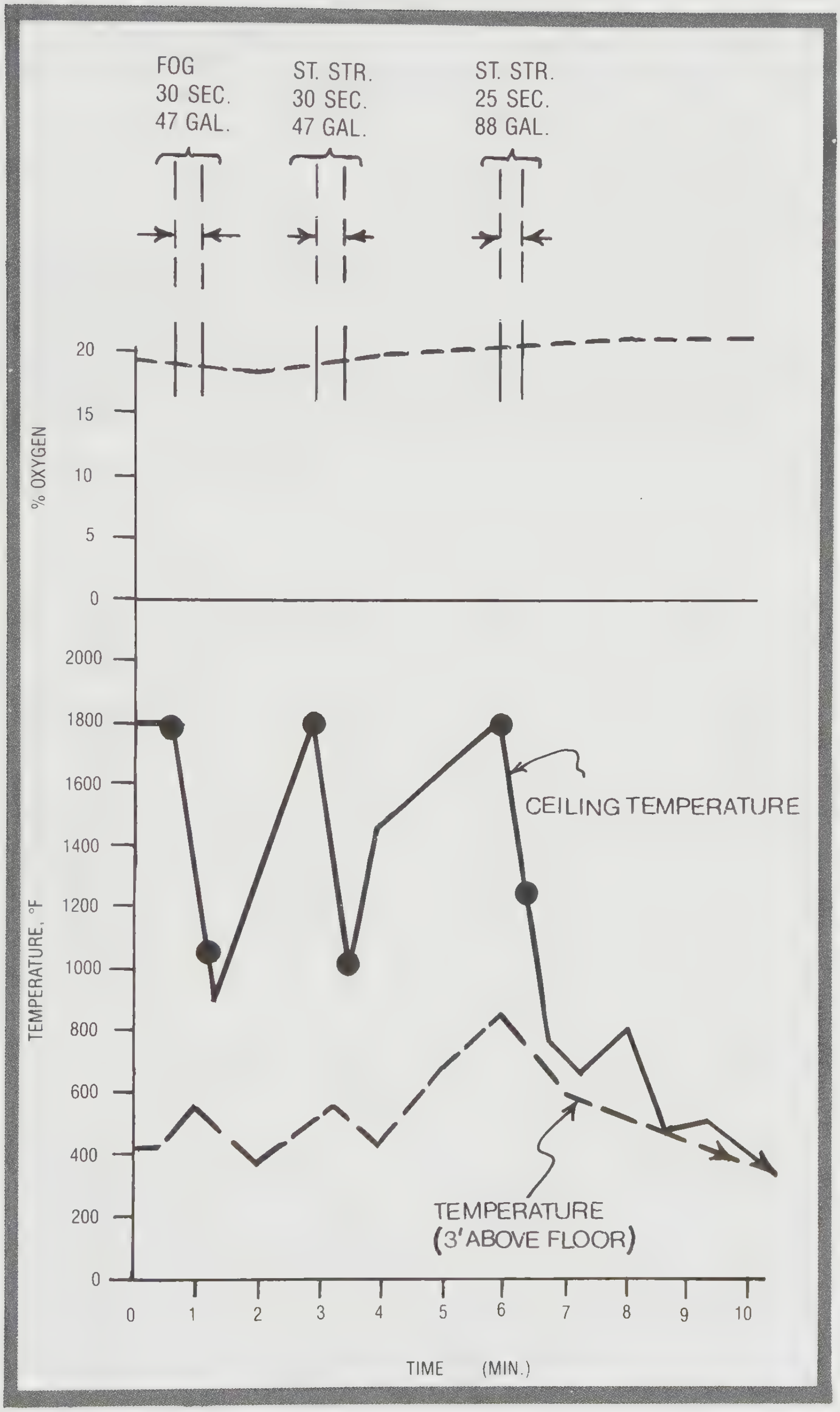
Therefore, it can be seen that use of water is hardly the ideal way to extinguish fire; it is just the way we have adopted, concentrated on over the centuries, and learned to accept as the most practical. There must be a better method waiting to be discovered, but, until then, our major effort should be to obtain the maximum benefit from the use of water as an extinguishing medium.

WATER FLOW AND FORM

There are two basic options available to the officer who is deciding on the method of applying water from a hose line. They are flow rate (in gallons per minute) and the form of the water (fog or straight stream).

From 1900 until 1939, the fire service in the United States virtually ignored the use of spray streams (hereafter referred to by the popular term, "fog"). Then, during the war years, fog nozzles were tried experimentally by a few fire departments. (Ironically, one of the types was a German invention.) The United States Navy, however, enthusiastically adopted a type of fog nozzle which was dubbed "all purpose," because it could be used for solid stream as well as fog. Harold J. Burke, a New York City deputy chief, became head of all

Figure 2.1. *Graph on facing page illustrates the effect of three different applications of water. The first application was 30-degree fog through a 95 gpm nozzle for 30 seconds, at 100 psi. The second application was with the same nozzle at the same pressure in the straight stream position for 30 seconds. The third application was in the form of a solid stream through a 1⅛-inch tip at a nozzle pressure of 32 psi for 25 seconds, in an attempt to apply the water at a rate twice as great as each of the first two applications. The temperatures measured at the ceiling and at a point three feet above the floor are shown on the lower part of the graph, while the oxygen content and water applications are shown at the top. The solid circles on the temperature line (ceiling temperature) show when the water was turned on and off. The advantage of the larger application is obvious; the temperature continued to drop even after the water had been shut off, because the fire had been knocked down almost completely. It is also clear that there is no major difference between the effect of fog and that of straight stream in the first two applications, indicating that adequate volume rather than pattern is the prime requisite for quick extinguishment.*



HIGHER VOLUME APPLICATION OF WATER (210 GPM VS. 95 GPM)
RESULTS IN QUICKER AND MORE LASTING EXTINGUISHMENT

Navy firefighting and training; he was a fog advocate. Thousands of sailors going through Navy fire schools were taught the use of fog on fuel oil fires in simulated ship engine rooms. The way in which fog worked on this type of fire (fuel oil) convinced many people that it was nothing short of miraculous. A lot of them went back to civilian life in municipal fire departments with this impression.

Lloyd Layman, the fire chief of Parkersburg, West Virginia, became a Coast Guard officer in charge of the Coast Guard fire school at Fort McHenry, Maryland. After the war, he wrote of his experiences with fog, both on ships and ashore, and gained quite a following for the method he termed "the indirect application of water fog."

Layman[1] is not fully to blame for the fanatical following his theory enjoyed. His writings were misinterpreted by his disciples, who ran wild, advocating indirect application to the exclusion of all other methods. They set the cause of ventilation back 50 years by urging that the fire building be closed up tight to prevent escape of the steam created when the water evaporated because of the heat of the fire.

Some fire chiefs were so overwhelmed by this new concept that they abandoned solid streams completely. The greatest proponents, however, were not the working fire chiefs, but insurance personnel and engineers who were captivated by the theoretical appeal of the indirect application of fog but who were not involved in actual firefighting. So convincing were their arguments that the theory became unquestionable, like the emperor's cloak.

It is interesting to note that the larger fire departments who dealt with the most fires were reluctant to jump on the fog bandwagon. In due time, many others discovered a considerable difference between what they read and what they saw, and fog was relegated to its proper place in firefighting.

FOG: THEORY AND PRACTICE

The first fog nozzle patented in the United States was one of the best ever designed. The patent was granted to Dr. John Oyston of Little Falls, New York, in August 1863. Oyston, whose doctorate was in mechanical engineering, was quite eloquent in furthering fog as the superior way to extinguish fires. He was quick to point out that the speed at which water will absorb heat is directly proportional to the amount of water surface that is exposed to the heat. When the water is broken into many small drops, a much larger water surface is exposed to the heat, and the smaller the drop, the faster it is evaporated into steam, thus absorbing the maximum amount of heat. (The heat of

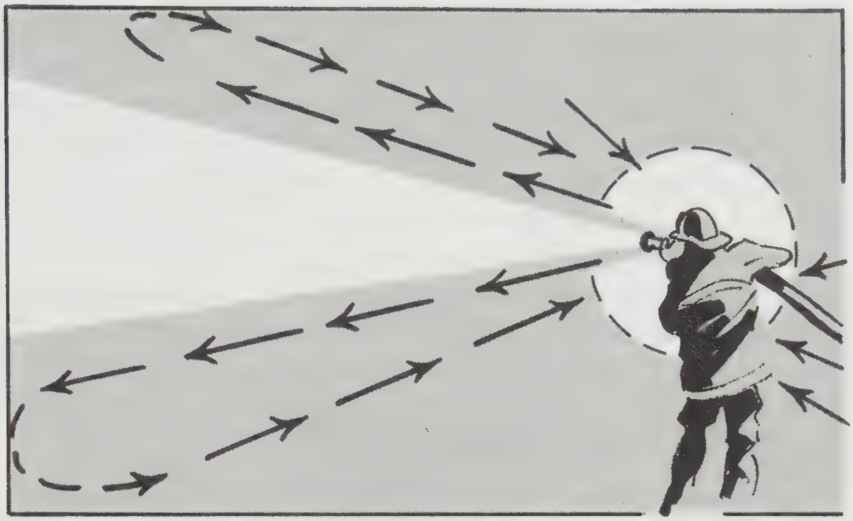


Figure 2.2. *Spray from a fog nozzle creates a low-pressure area at the nozzle orifice, which in turn creates air currents that carry air or smoke back to the nozzle.*

fusion is 79 cal/g, the heat of vaporization is 536 cal/g—an absorption rate more than six times greater.) Therefore, a given amount of water will absorb more heat in the form of fog and a greater percentage of it will be turned into steam, which expands the water 1,650 times, thus displacing and diluting the oxygen in the fire area to decrease combustion further. Since more water is converted into steam, there is less damage from water run-off. This information is all true—theoretically.

But does it always work out this way in actual practice? No! In experiments on actual fires, we have found that conceptual knowledge and perceptual knowledge are not in agreement. In most cases, fog is no better, or not as good as, a straight stream. This result can be explained when we ponder the fact that the finely divided spray cools the atmosphere of a confined space quite effectively, but we are not primarily interested in that. We realize that extinguishment occurs through cooling the fuel source to the point where it will stop generating fuel gases.

In a series of tests made by the Joint Fire Research Organization at Birmingham, England, 12 fires in furnished rooms of 1,500-cubic-foot volume were extinguished with 40 gpm (imperial) streams at 100 psi to show up any potential differences between sprays and solid streams. The report states, "No such difference appeared." Yet rooms of such small dimensions should be ideal for spray application, because, as the same report further states, "As the size of the room in increased, the size of its internal surface becomes less in comparison with its volume due to the scaling law . . . It becomes progressively more difficult to provide the steam required to fill the room by evaporation of water at the hot surfaces. The mechanism of extinction then probably changes gradually from one of smothering with some cooling of solids, to one of much cooling of the solids with some smothering. This may well provide the explanation of the reduction in the efficiency of extinction [by spray] as the size of the room is increased."[2]

Rabasch[3] says, "In order for spray to be able to exert a useful effect on a fire, it is usually necessary for the spray to penetrate to the seat of the fire, particularly to the burning fuel [source]."

He submits a series of four equations which show that, "much lower critical flow rates would be expected for cooling the fuel (source) than by cooling the flame."

CRITICAL RATE FOR EACH FIRE

Fortunately, during well-developed fires in enclosures, a high percentage of the heat is dissipated. Some is lost to the outside by both convection and radiation through openings, and some is absorbed or conducted by incombustible materials. Consequently, only a portion of the heat given off must be absorbed by the water applied. Theoretically, about one gallon of water is needed to absorb the heat generated by a pound of burning wood, and so it would take about 500 gallons per minute (gpm) to absorb the heat generated by wood burning at the rate of 500 pounds per minute. In actual practice, less than half that flow would probably darken the fire quickly.

When a fire continues to burn after water has been applied, it is for one of two reasons. Either the water is not reaching the burning material, or it is not being applied at a sufficient rate of flow. The critical flow rate is the minimum flow in gallons per minute needed to extinguish a given fire. A flow greater than the critical rate will extinguish the fire, but a flow less than the critical rate will not. There is a critical rate for each fire, whether the water is being applied in the form of high-pressure fog, ordinary fog, or a solid stream. If that rate is not reached or exceeded, the fire will continue to burn.

High-pressure fog (600–800 psi nozzle pressure) presents water in its most finely divided form. High-pressure fog streams are usually limited to about 30 gpm, however, and should not be expected to extinguish fires which call for a higher critical rate.

A stream from a 1½-inch hose line delivering 95 gpm is not sufficient to extinguish a fire calling for a higher critical rate of flow, whether the nozzle be set at wide fog, narrow fog, or straight stream.

STEAM EXTINGUISHMENT

The extinguishing effect of steam is very limited. If there are openings through which the steam can escape, it will have virtually no effect; steam's efficiency is in inverse proportion to the amount of ventilation. It dissipates rapidly through all openings and is quickly replaced by air. As the air replaces the steam, hot surfaces of solid fuel sources reignite and soon burn as intensely as before; however, flammable-liquid fires will not rekindle. The difference is due to the ability of the solid to retain heat longer.

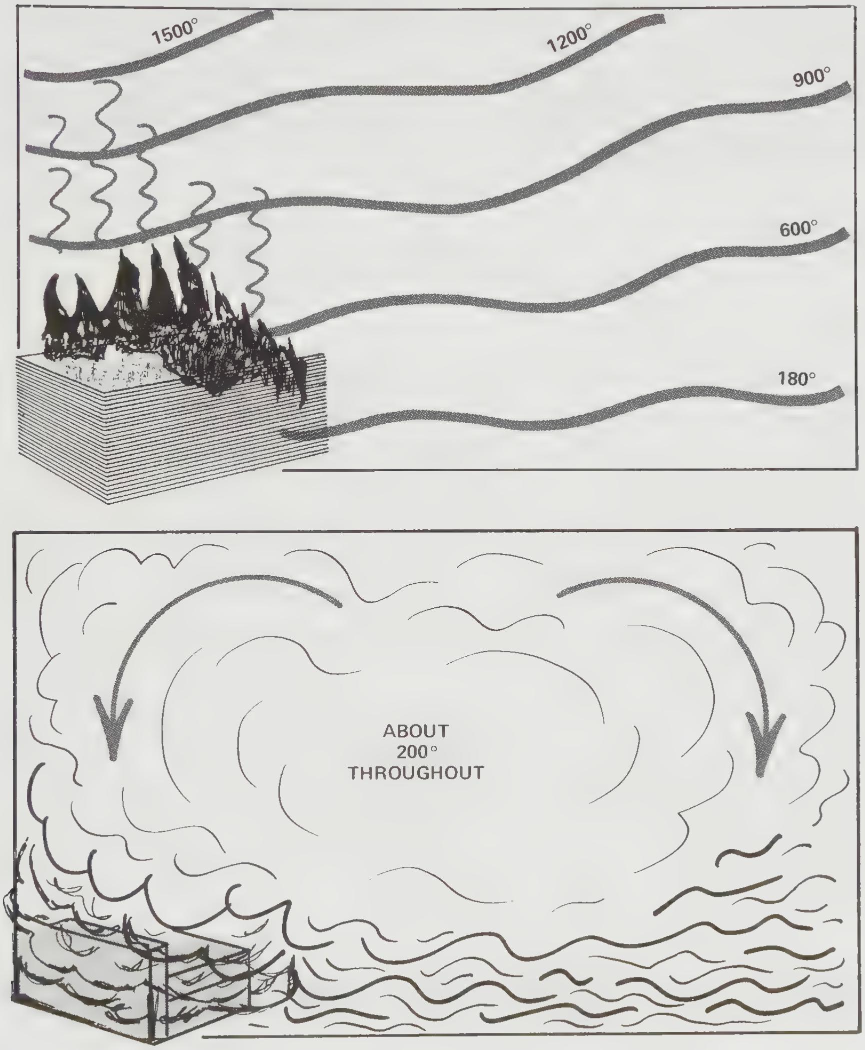


Figure 2.3. *The natural layering of heat in a room (**A.**) causes a considerable range in temperature between ceiling and floor. Water fog disrupts this layering and creates an almost uniform temperature throughout the room (**B.**), actually causing an increase in temperature at the lowest level and sometimes causing skin burns.*

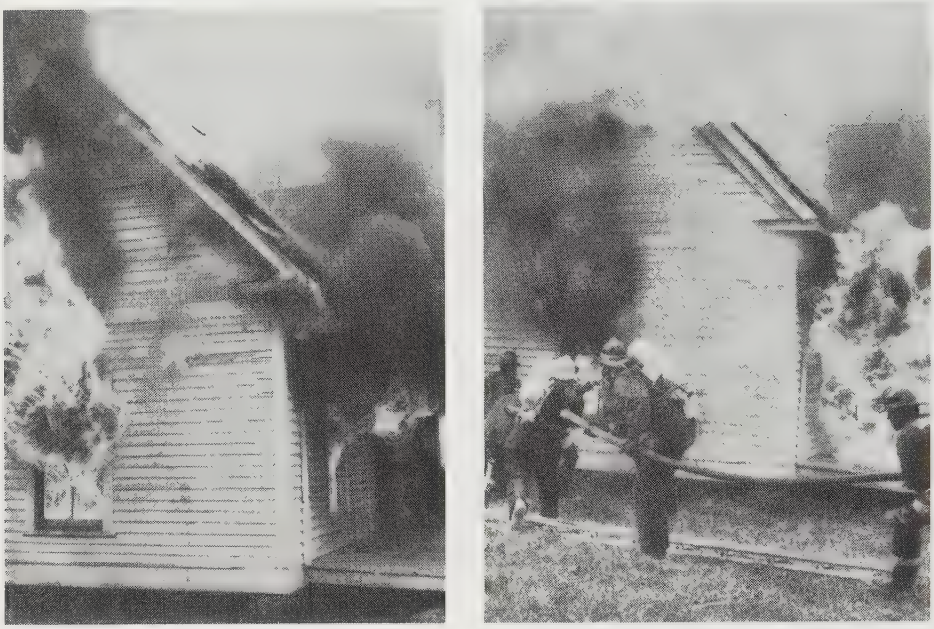


Figure 2.4. A. This test fire was permitted to burn until flashover occurred and flame was pushing out through the windows; fire was in one room.
B. Stream from fog nozzle was then played through the window at the left. Force of the entrained air (much greater for fog than for straight stream) drove fire throughout the first floor.

For water to be turned into the maximum amount of steam, it must strike the hot surfaces of ceiling and walls, although some of it will evaporate while passing through hot gases. The rapidly expanding steam can fill confined spaces such as ceilings, attics, and cocklofts and dilute the oxygen to the point where combustion will cease while the steam is present. But, as the steam cools, it contracts in volume and thus allows air to enter and reignition to occur. For this reason, quick follow-up may be needed to get water directly into such spaces as the steam dissipates.

Steam is invisible. When water vapor can be seen, it is no longer steam but has cooled below the boiling point (212° F) and is condensing. This vapor is almost white in color when it reaches the outside air. If, as it thins out, darker vapors can be seen coming out with it, that is a sign that combustion is continuing and may intensify rapidly as more air enters.

SOLID AND STRAIGHT STREAMS

Solid streams from smoothbore nozzles and straight streams from fog nozzles provide reach and penetration. This ability is of particular advantage at fires in fibrous materials or at fires involving stacked or

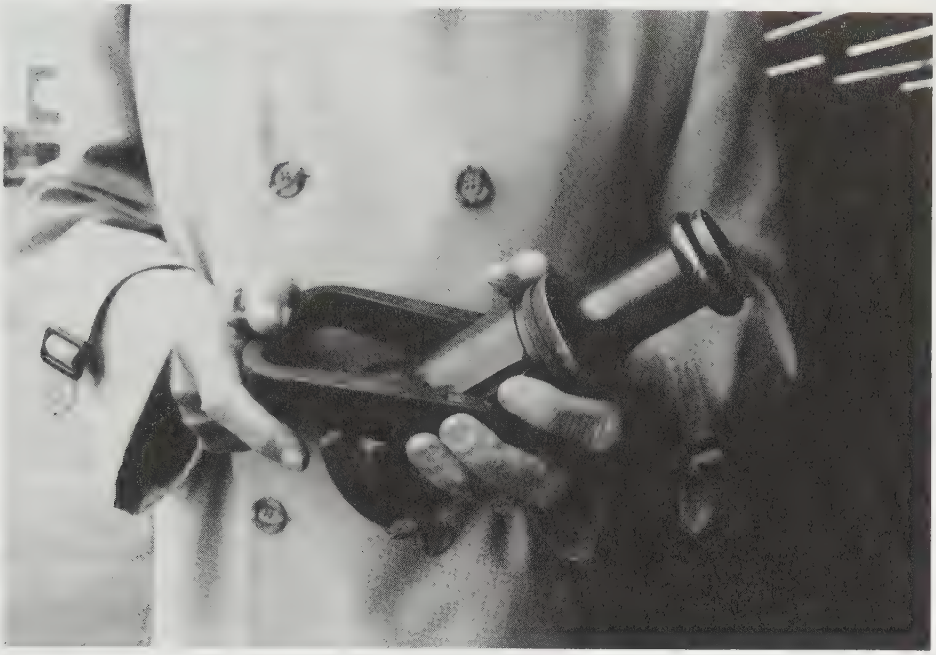


Figure 2.5. *After using several kinds of fog nozzles for over 20 years, New York City returned to the N.Y.C. standard solid stream type in a lightweight alloy. The compact size and light weight require less effort and give greater maneuverability. Solid stream nozzles mean fewer, if any, steam burns and provide more extinguishing power at less pressure, but they lack the versatility of variable pattern nozzles. The nozzle shown above is for 2½-inch hose and has a 1⅛-inch tip. The model for 1¾-inch hose has a 15/16-inch tip. Both sizes have a removable ½-inch tip* (not shown) *and may be taken apart to allow hose to be extended from the valve.*

baled materials, especially in outdoor storage, where the stream is aimed to strike the burning material. At well-developed indoor fires, however, a straight stream is used effectively by bouncing it off the ceiling over the fire. The water then falls in large drops on to the burning material. The heavy drops penetrate the rising gases without being evaporated en route. With this method the major portion of the water reaches the surface of the fuel source in a fairly well-divided form to absorb heat where cooling is needed most. Furthermore, there is little evaporation of the water stream between nozzle and ceiling. Cooling of the ceiling is another benefit, especially if flashover may be imminent.

Some advantages of solid streams are that they discharge water at greater distances and at much lower nozzle pressures than fog streams (Figure 2.5). This fact is not critical at small fires where 1½-inch hose is being used, but it is at fires calling for 2½-inch hand lines and master streams. When 2½-inch hose is being used with a nozzle pressure of 100 psi—which is the manufacturers' recommended pressure for nearly all fog nozzles—the hose is so stiff that it is extremely difficult to bend and requires additional personnel to advance, especially where several turns have to be made. Furthermore, higher nozzle pressures require higher pump pressures, and the needed difference may be beyond the capability of the pump in some situations. (The difficulty of maneuvering hose at 100 psi has led many departments to use lower pressures and consequently get lower flows. A nozzle is needed that will give good flows at lower pressures.)

Some examples of the nozzle pressures, pump pressures, and reach, if 400 feet of 2½-inch hose are used, follow:

Tip (inches)	*gpm*	*Nozzle Pressure (psi)*	*Pump Pressure (psi)*	*Reach[a] (feet)*
Fog	250	100	160	42
1⅛	251	45	105	104
1¼	253	30	90	104

[a] Maximum distance at which stream extinguished a fire involving 500 pounds of wood pallets

DISADVANTAGES OF FOG

The amount of air entrained by a fog stream is far greater than the amount with a straight stream, which can be an advantage or a disadvantage, depending upon the situation. About the only time it is advantageous is when you are advancing in a narrow corridor or stair where the fog can induce a good flow of air from the open doorway behind. At all other times within a structure, the low-pressure area at the nozzle will attract smoke and heat to that point.

A serious disadvantage occurs on occasions when the water is not striking the fire, but the air driven ahead of the fog stream fans the fire, which not only happens in rooms but also in ceilings. I have seen a fog stream fan a small fire in a ceiling tenfold in a few seconds when the stream was directed into a hole in the ceiling.

When a fog nozzle is directed through a doorway into a room with no other outlet available for the entrained air to escape, it will force the fire back along the ceiling toward the nozzle, and flames may shoot through the top of the doorway. If the firefighters at the nozzle are standing instead of kneeling, they may be burned.

Another disadvantage of fog occurs when it upsets the thermal balance. Heat from a fire characteristically banks down from the ceiling, and it is common for the ceiling temperature to be more than 1,000°F higher than the temperature at the floor. This layering of the heat enables firefighters to get into the fire area, because a human being can endure dry air of about 300°F without much difficulty. But when fog is applied, the temperature at the ceiling drops to about 200° and the temperature at the floor increases to about 200°, in what is now very moist air, which is above the level of human tolerance. Many firemen have been burned in this fashion. And on many occasions firemen have been driven out of a building or kept from entering it by this upsetting of the thermal layers.

Bouncing the straight stream off the ceiling does not suddenly change the proportion between heat intensity at the ceiling and the floor. The temperature at the ceiling is lowered without an increase in temperature at the floor, and the atmosphere at the floor remains tolerable because less steam is there.

The discussion so far has centered on what might be called high-intensity fires, i.e., those where the temperature at the ceiling exceeds 1,000°F. Only in such fires can a sufficient amount of steam be developed for the indirect fog method to be effective. Fires with lower ceiling temperatures usually require direct application of the water to the burning material, whether it be furniture, merchandise, or rubbish.

The use of fog on outdoor fires involving solid fuel sources is not advisable. The reach and penetrating ability of straight streams prove much more effective, and steam production is of no consequence.

In summarizing the relative merits of fog and straight streams, it should be recognized that each has a place where it more efficient that the other. Fog is effective on high-flash-point-liquid fires (those in the kerosene class or higher); straight streams are not usually effective on liquid fires. Fog is desirable when steam generation is wanted to force steam into inaccessible areas. For this process to be effective, however, there must be a continuing flow of steam for several minutes—a difficult achievement unless the rate of water application is not great enough to extinguish the main body of fire, which makes for a rather ambiguous situation. In all other situations, the extinguishing effect and general efficiency of straight streams is as good as, or superior to, fog.

Test were made at fires in furnished rooms of buildings scheduled for demolition. Variable factors were held to a minimum by having the fires in the same or similar rooms and with similar fuel loads for each comparison, and by applying water at the same rate in both fog and straight streams. In some cases we applied a given total amount of water at different rates. A clearer picture of the methods may be shown by the following:

Test No. S-1, Three Trials

Trial A: High-pressure fog: 800 psi nozzle pressure (30 gpm)
Trial B: Low-pressure fog: 100 psi nozzle pressure (60 gpm)

Trial C: Solid stream: ½-inch tip, 66 psi nozzle pressure (60 gpm)

The same room and fuel load were used in each trial except that a few additional pounds of fuel source were added after each fire to make up for the amount burned.

Method: When the ceiling temperature reached 1,200°F, the nozzle was opened and kept open until 15 gallons of water had been applied. Then the room and contents were examined to note how much fire remained. A hole had been cut at the lowest point in the floor and a catch basin placed beneath it to collect run-off, which was measured five minutes after the nozzle was shut off.

Results: Trial A: The sofa was still showing a small amount of flaming combustion. Smoldering was noticeable at several points in the room. Run-off was three quarts.

Trial B: No flame was visible. There was smoldering at several points, but less than in Trial A. Run-off was also three quarts.

Trial C: No visible flame; smoldering at a few points was much less than in Trials A or B. Run-off was less than one quart.

The other type of comparison was run as follows:

Test No. W.D. 1

Trial A: When the ceiling temperature reached 1,100°F, water was applied with a 75-gpm fog nozzle at 100 psi until flame and smoke production ceased. The amount of water used was 30 gallons. The time was 24 seconds. Run-off was two gallons.

Trial B: When the ceiling temperature reached 1,100°F, water was applied with a ⅝-inch tip at 43 psi (75 gpm) until flame and smoke production ceased. The amount of water was 20 gallons. The time was 16 seconds. Run-off was less than one quart.

In all of the above trials, the fog nozzle was aimed through a window and rotated rapidly to cover as much of the room as possible. The solid stream nozzle was used from a doorway, aimed to strike the ceiling and rotated rapidly to cover as much of the room as possible with the water deflected from the ceiling. These methods of application were used because they are the commonly practiced methods of using each type of nozzle. In some other trials, both fog and solid streams were applied from the same point, usually a doorway, with results similar to those described above.

There has been criticism of these data because of the small amounts of water reported both for extinguishment and run-off. Of course, these were test fires with the benefit of careful control and timing and without the stress of "real" fire situations. Yet not only these tests but a study by Illinois Institute of Technology Research

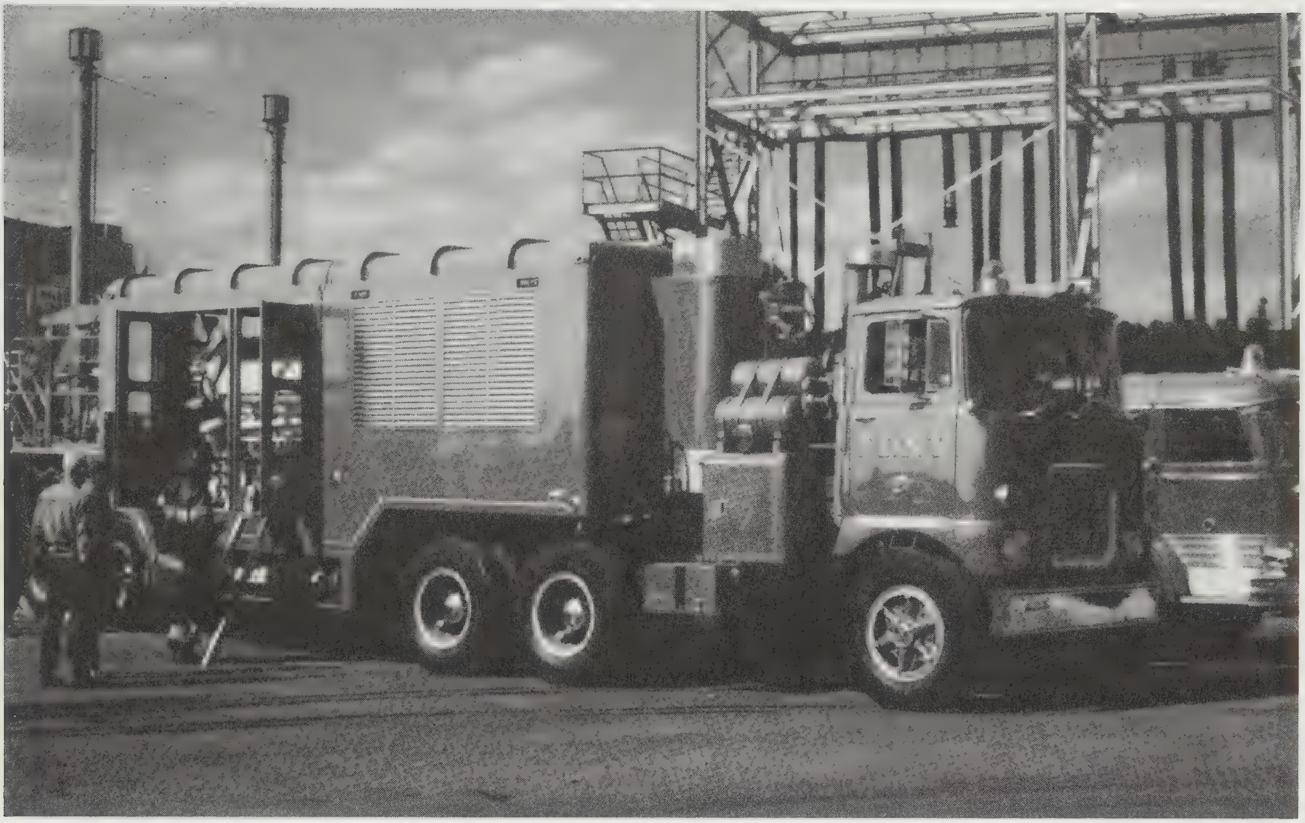


Figure 2.6. *The super pumper was one of the few new concepts in twentieth-century firefighting. Only one was ever built in the U.S., and it served well from 1965 to 1982 in New York City. It responded to more than 2,000 large fires and worked at almost half of them, pumping over 100 million gallons. It could pump 10,000 gpm at 300 psi or 4,400 gpm at 700 psi. The system had nozzle tips as large as five inches in diameter. That size gave a stream of 8,000 gpm at 125 psi nozzle pressure, which could demolish substantial structures. It once pumped through 7,000 feet of 4½-inch hose and helped to make large-diameter hose popular. Although the super pumper has been retired due to wear and difficulty in replacing parts, the concept of large-diameter hose seems to be here to stay.*

Institute (IITRI) showed that far more water is used at unplanned fires than at controlled tests. This fact indicates that, usually, more water is being applied than is needed at real fires.

The IITRI tests were performed in full-sized rooms, fully furnished. The fires were started in furniture and attacked at different stages of development. Pre-flashover fires were extinguished with two gallons or less, from a pump tank; post-flashover fires averaged 15 gallons for single rooms to 48 gallons for a two-room fire, applied by hose streams varying from 18 to 30 gpm.

Their study of 27 actual fires in a metropolitan area shows a great variance in the total amount of water applied and the application rates reported by fire departments.

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Rule of thumb wo water

WHEN NOT TO USE WATER

There are times when water in any form is not effective, and there are times when it is dangerous to use. Water fog is not effective on gasoline fires or fires in other liquids with flash points under 100°F, unless the rate of flow is very high in proportion to the amount of fire. For instance, a rate of 190 gpm will not extinguish a 50-square-foot heptane fire, which a hand portable extinguisher must extinguish to get a 20-B rating.

Water is not an effective extinguishing agent on most fires in metallic dusts and shavings, or in pyrophoric metals (termed Class D fires).

There are materials which react unfavorably with water. Sodium reacts violently; calcium carbide generates acetylene, which is a highly flammable gas. There is a simple rule of thumb which can be used as a guide for the substances on which it is dangerous to use water: Beware of substances in which the first name ends in "*um*" and the second name in "*ide*." (The table of common hazardous chemicals lists but three exceptions to this rule: chromium trioxide, potassium sulfide, and sodium sulfide.) This rule is used because oxides of metals react with water to form bases, and oxides of non-metals react to form acids, with a release of heat, which is sometimes violent. Peroxides will release oxygen as well as heat.

Fortunately, there are agents that will extinguish fires on which water is not effective. But unfortunately—with the exception of foam—they are usually available only in quantities suitable for small fires. The most effective and widely used of these extinguishing agents are: protein foam, aqueous film-forming foam, detergent foam, sodium bicarbonate, potassium bicarbonate, monoammonium phosphate, potassium carbamate, and halogenated hydrocarbons (halons).

Water extinguishes fire through removal of the fuel leg of the fire tetrahedron by cooling the fuel source to a point where it no longer emits a fuel vapor—a physical action, especially effective on solid fuel sources and high-flash-point liquids.

The second method of extinguishment is the dilution or exclusion of oxygen in the fire zone to a point at which combustion will cease. The use of carbon dioxide (CO_2) is the leading example of this method, which is more chemical than physical, but is partly both.

The third is blanketing the fire with a layer of material excluding oxygen by purely physical means. Examples are a wet or incombustible blanket; a layer of foam on a liquid surface; a film on solid fuel, as when multi-purpose dry chemical intumesces on a wood surface; or when boron trifluoride, or similar agents for Class D fires, coat a combustible metal.

The fourth means is the interruption of the combustion chain reaction, usually accomplished through the application of the various dry chemicals and halogenated hydrocarbons.

There is only one water (H_2O) and only one carbon dioxide (CO_2) but there are several foams, dry chemicals, and halogenated hydrocarbons, all of which vary in effectiveness and side effects.

FIREFIGHTING FOAMS

In the late 1800s, a method of extinguishing flammable-liquid fires by blanketing them with foam was introduced. The original foam was made by mixing two separate powders with water in a "foam generator." The product was a thick stable blanket of bubbles containing carbon dioxide. For years it was thought that the carbon dioxide was important to the extinguishing action, but this effect was later found to be of little consequence. The extinguishment is possible because the foam, which is lighter than the burning liquid, will float on top of it and "smother" the fire by excluding air (removing the oxygen side of the tetrahedron). The foam blanket also suppresses the release of flammable vapors by the liquid, thereby removing the fuel side. There is some cooling, but that is usually a minor consideration. Later, the two-powder form was replaced by a single-powder concentrate, which also reacted with water to create a similar foam. Both of these foams were called "chemical foams" because they were created by chemical action.

In the 1940s, a new type of foam was introduced; it was made by mechanical rather than chemical action, when a protein-based concentrate was mixed with water in either a proportioner or an aerating nozzle, forming bubbles containing air, not carbon dioxide. This type was named "mechanical" foam and soon became popular because of its expansion ratio, free-flowing characteristic, and ease of handling.

Then came surfactant (detergent) foams, which offered further advantages. First, they could be used together with dry chemicals, which destroy protein foam. They had a better shelf life than protein form, and, furthermore, they could be used as wetting agents on solid combustibles, penetrating the surface to extinguish subsurface combustion. The surfactants were called, "water wetters," and the product, "wet water."

Mechanical foams can be applied through fixed installations or by portable equipment such as aerating nozzles or proportioning devices, placed in hose lines to mix liquid foam concentrate with water in the proper proportion. There are several types of foam available, with somewhat different characteristics. Those most widely used are described below.

Protein Foam

Protein foam is so called because it is made from natural animal protein, such as the hooves of cattle, mixed with metallic salts and other additives. When properly proportioned and aerated, it gives a dense, viscous, and stable blanket with good resistance to heat and burnback, but it is comparatively slow-spreading.

It is easily contaminated by some flammable liquids because it does not shed them well. Therefore, it is not suitable for subsurface injection; care should be taken to apply protein foam in a way that won't plunge it beneath the fuel surface, because, when it rises to the top, it may have lost much of its effectiveness and could allow reignition.

Moreover, it is unsuitable for use on polar solvents. It is incompatible with dry chemical and could lose its effectiveness when used with that.

Fluoroprotein Foam

The next type of foam is fluoroprotein foam, which contains as an active agent a fluorinated surfactant, which supplies an oil-rejecting property to prevent contamination. Thus, fluoroprotein foam will shed hydrocarbon fuels and can be used for subsurface application. It is generally better than plain protein foam or A.F.F.F. (see below) in resisting burnback and reignition. Its longer blanket life provides better safety when entry is necessary for rescue or other reasons. It is compatible with dry chemical, and it can be applied over A.F.F.F. when a longer-lasting blanket is wanted.

A.F.F.F.

A third type of foam is called A.F.F.F. (usually pronounced "A triple F," which is short for "aqueous film-forming foam"). This solution possesses low viscosity and is fast-spreading, thus providing a quicker knockdown of the flames. It also forms, under the foam bubbles, an aqueous (water) film, which can cool the fuel liquid and stop formation of flammable vapors.

It is effective in subsurface applications, but it is particularly good on spill fires. A.F.F.F. can be applied by regular fog nozzles, but, when it is, the solution drains fast and has less burnback resistance.

A.F.F.F. is compatible with dry chemical. This quality, and its quick knockdown capability, makes it a favorite for aircraft crash operations. It has, however, poorer resistance to burnback than fluoroprotein foam and exhibits more rapid water drainage.

F.F.F.P.

A fourth kind of foam is called "film-forming fluoroprotein" (F.F.F.P.) This type contains protein combined with film-forming fluorosurfactants to provide a balance between A.F.F.F. and fluoroprotein. It is film-forming and fast-flowing, and the protein base gives good heat and burnback resistance.

Polar Solvent Foams

Some flammable liquids resist extinguishment by the foams already mentioned. These liquids are called "polar solvents," and they include alcohol, esters, ketones, acetone, lacquer thinners, and other water-soluble fluids; they combine with the water in ordinary foam and so destroy the blanket. Therefore, concentrates have been developed which contain additives that form a barrier between the surface of the flammable liquids and the foam blanket and so prevent the water in the foam from combining with the fuel liquid. If plunged beneath the surface, this type of foam will deteriorate rapidly. Polar solvent foams are useful on hydrocarbon fuels, too, but they are not as effective as the others. They can be applied with either aspirating or non-aspirating nozzles.

Since unleaded gasoline and gasohol both contain polar solvents, the question arises as to whether they can be extinguished by the other foams or require polar solvent foams. The answer may depend upon the size of the fire and other conditions. The regular foams can be effective on spill fires, especially small ones. The foam blanket will not last as long, but that can be compensated for by application of more foam until the danger of reignition is past.

Most fires involving liquids fall into three basic categories: shallow spill fires, deeper spill fires, and deep-seated fires.

The shallow spill, such as that from an aircraft crash or overturned tank truck, may cover a large, irregular area. Fast-flowing and low critical application rates are desirable foam characteristics in this situation. Fuel tolerance, heat, and burnback resistance are requirements of lower priority.

The deeper spill occurs in a contained area, such as one within a dike, where there is some depth of liquid fuel, but not great depth. This type may require more fuel tolerance and heat resistance than the shallow spill.

The deep-seated fire is found in storage tanks, where deep fuel liquid levels and high temperatures require a foam with good fuel tolerance and burnback resistance, and less demand for free-flowing characteristics.

If, in any of the above types of fire, there are obstructions or debris, faster-flowing foams may be preferable, but there must be adequate protection from reignition, as well.

Making Foam

All of the foams described are available in two concentrations: 3 percent and 6 percent; not knowing the difference can cause trouble. Using the lower percentage when the higher should be used will make a weak foam with short drainage time and poor burnback resistance. Conversely, if the mixture is too rich, the foam will be too stiff to flow freely around obstructions and will use up the concentrate faster.

The specified percentage, therefore, should be matched with the proportioning device. Some proportioners are adjustable in percentage and should be set at the proper proportion. (Three percent means the resulting foam mixture will contain 3 percent concentrate and 97 percent water. The 6 percent concentrate is meant to mix with 94 percent water).

Pressure proportioners exist for use on special foam trucks and fixed systems, but the proportioner popular with fire departments is the in-line eductor, which sucks the foam concentrate out of its can through a pickup tube. This step is performed when the water, flowing at increased velocity through a venturi in the proportioner, creates sufficient vacuum. Some eductors are put in the hose line; others, at the nozzle. The latter limits mobility somewhat.

Inasmuch as these eductors come in several flow capacities, it is important that the nozzle to be used is matched with the flow of the eductor: a 60 gpm nozzle with a 60 gpm eductor; a 95 gpm with a 95 gpm, and so on. A mismatch can result in a weak, ineffective foam or possibly none at all. Eductors are available in several flow types. Nozzles should be matched accordingly.

The foam playpipe or nozzle also has a venturi to draw air in to mix with the solution of foam concentrate and water in the form of bubbles. When aerated, the foam-air solution will expand to several times its original volume as it leaves the nozzle. Each model of nozzle has a definite expansion ratio, which indicates the volume of final foam it will produce in relation to the amount of foam concentrate used. Nozzle pressure can vary upward from 70 psi, but 100 psi is usually recommended.

Some foam nozzles are designed to provide foam in spray form. Others are made to project it in a straight stream. (Application techniques will be discussed later in this book, in the section dealing with flammable liquid fires.) Note here, however, that flow requirements vary with the type of foam, but can be calculated easily. There is an application rate for each type recommended by the NFPA or the manufacturer. When this number is multiplied by the amount of square feet to be covered, it should give the required rate of final foam.

Because of the variety of foam concentrates and foam-making equipment, it is well to become familiar with the instructions and recommendations of the manufacturers regarding their care and use.

High-Expansion Foam

There is another type of foam which deserves attention, and for two reasons. One of these is that it is applied differently from any other foams; the other is that it can be used successfully on structural fires. It is a detergent type of foam with a high expansion ratio, which is called "high-expansion" foam.

In all of this century there have been but two significant breakthroughs in fire extinguishing agents. One is the multi-purpose (A,B,C) dry chemical; the other is high-expansion foam. The latter is a valuable tool, which has not been fully understood or used.

High-expansion foam was developed in England (and almost simultaneously in the United States) for use on coal mine fires. In the early 1960s, when it was still in the development stage, its ability to extinguish building fires was recognized; however, because it was a new medium, a combination of overenthusiasm and lack of knowledge led to mistakes in its use. A reappraisal, based on better understanding of it, is now due.

The effectiveness of high-expansion foam is limited by two factors: the "block" pressure of the fan or other device applying it, and the configuration of the fire structure. In some cases, it gives results that are marvelous; in others, it gives no satisfaction at all. The fire officer should know the factors that determine the difference.

High-expansion foam has a dual effect on fire. It contains water which cools the fire. When the large amounts of steam resulting from the application of high-expansion foam are seen, it appears that the cooling effect of the water is a principal extinguishing force and that the foam bubbles serve best as a means of conveying the water to the fire. Yet there is evidence of a smothering effect caused by the foam trapping the products of combustion (mostly carbon dioxide) on the surface of the burning materials and also separating the fuel source from the oxygen in the atmosphere. Although this foam is not quite as effective on liquid fires as protein or aqueous film-forming foams, it can extinguish fires from solid fuel sources quite effectively.

The factors affecting the success of high-expansion foam in extinguishing fires inside buildings are:

1. The foam will go no farther than the propelling force (electric or water motor fan, or other means) can push it. With the smaller units, this distance is about 75 feet horizontally and 30 feet vertically.
2. A most important factor is that as the foam builds up in an area such as a basement, it builds up from the floor at the angle of repose. As it rises, it pushes the air in the room upward. If there is no hole for the air to escape through, it will be compressed until it reaches the block pressure of the foam-making machine. Then the foam and air pressures will be in equilibrium, and no further elevation of foam can take place. This condition leaves a cushion of air under the ceiling where fire can continue to burn. The heat of this fire dissolves the top layer of the foam, and thus a condition is set up where the generator keeps sending in just enough foam to replace that dissolved by the heat, and the fire continues. This process is the reason why cases have been reported wherein the fire department used much more foam than the basement could hold and yet didn't extinguish the fire. The remedy is to put a small hole in the ceiling from above for the air to escape through. As the air is pushed up through the hole, the foam will rise and touch the ceiling, thus filling the whole room (or basement).
3. The foam has the fluidity of a liquid rather than a gas and cannot travel through tiny cracks, around closed doors, or through walls or other obstructions. It should not be expected to perform miracles.

On some occasions, the foam will slow up a fire to the point where hand lines can be taken into the building for final extinguishment. A firefighter can walk through the foam, but the footing will be slippery and due caution should be taken to avoid falls. A man died from such a fall on a concrete floor.

When high-expansion foam has been applied from one location without satisfactory progress, it should be tried from another; it may have been kept from the fire by an obstruction. Usually when foam is reaching the fire there will be a noticeable amount of condensing steam.

While foam is filling a basement, the fire may be getting up in the walls. Frequent checks for this movement should be made and precautions taken to head off the upward travel of fire.

OTHER WATER ADDITIVES

There has been much experimentation with other additives, mainly to thicken water in order to make an insulating barrier on the surface of solid fuel sources to reduce the run-off of water. The only practical use of these additives (borates, bentonite, methyl cellulose) has been in airplane drops on forest and brush fires. One of the problems they present is that of proportioning the additive with water. Special equipment is needed to induce it into a hose line.

Another water additive, the polymer known as "rapid water," does not enter into the extinguishing action of the water to which it is added. Its purpose is to reduce friction loss in hose. It was used in some cities in the 1970s but not for long.

FIRE-EXTINGUISHING CHEMICALS

Recent years have seen several advances in fire-extinguishing chemicals—notably dry chemicals.

The original dry chemical was sodium bicarbonate, which has been used for a hundred years, but which became very popular for use on flammable liquid fires when improved methods of applying it were developed shortly after World War II. It is still in wide use.

Then it was discovered that potassium bicarbonate, Purple K, was more effective on flammable liquid fires than sodium bicarbonate.

About 1959, a most revolutionary extinguishing agent was brought here from Germany—a dry chemical that was effective in extinguishing fires in solid as well as liquid fuel. The agent, monoammonium phosphate, became the first dry chemical that was effective on three classes of fire, and thereby became widely known as "A,B,C" or "multi-purpose" dry chemical.

The latest agent to enter the dry chemical field was developed recently in England and is now available in North America. It has a potassium carbamate base and a rating indicating that it is much more effective on flammable-liquid fires than the three dry chemicals mentioned above.

In the early 1960s, a new halogenated hydrocarbon was introduced which was not only an effective extinguishing agent but was much less toxic than its earlier relatives. This substance was named bromotrifluoromethane, or "Halon 1301," for short. In addition to low toxicity, it has the further advantage of doing its work in gaseous form with no mess or residue.

These latter qualities made it popular for use in fixed installations that protected sensitive equipment, such as computers, where liquids or powders would create expensive cleanup problems. Halon 1301 is rated as much more effective than carbon dioxide for total flooding of closed rooms, cabinets, or other confined spaces. It is believed that the halons extinguish fire by interrupting the combustion chain reaction. In order to preserve the low order of toxicity, a system must be engineered to extinguish the fire quickly to limit the formation of hydrogen fluoride. Another halon that is widely used is "1211."

Research on halogenated hydrocarbons is very active, and new halons will probably be introduced which will be even more effective. The fire service should keep abreast of these fixed installation developments, especially in regard to toxicity after thermal decomposition of the extinguishing agent. As one who has inhaled the products of decomposed carbon tetrachloride at a fire—but was fortunate enough to survive—I should like to pass on this warning.

Since it has been claimed that halons are having an adverse effect on the atmosphere, legislation may limit their use in the future.

NOTES

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2. Rabasch, D.J., and Nash, P.: *Annual Report*. London, Institution of Fire Engineers, 1955.
3. Rabasch, D.J.: *Extinction of Fires by Water Sprays*. Washington, D.C.: Fire Research Abstracts and Reviews 4, 1962.

3

The Development of Firefighting

THE DIFFERENCE between strategy and tactics is hard to define. It seems safe to say, however, that strategy is the large-scale general plan and that tactics are the ways of implementing the strategy. Gratz[1] gives a firefighting example in which the strategy calls for taking a hose line to the fourth floor of a building to prevent upward extension of a third-floor fire. He says the idea of placing the line on the fourth floor is strategy, but the method of getting it there is a tactic.

Strategy in firefighting developed slowly over a long period of time, and it has been altered somewhat with changing conditions and improvements in firefighting equipment, but it has changed remarkably little in basic concepts since hose was introduced.

It is a great help in understanding a situation if one knows how and why that situation evolved. Prior to the introduction of hose (in Holland in 1672), firefighting was carried on with buckets of water or a hand-operated pumping engine with a nozzle affixed to the engine, similar to today's deckpipe. The only other firefighting tool of significance was the "pull-down" hook used to remove thatched roofs and sometimes demolish buildings in the path of the fire, a rather crude method of exposure protection. The priority given to preventing the spread of the fire has carried down to the present day. The basic rules of firefighting strategy are still:

1. Locate the fire.
2. Confine it.
3. Extinguish it.

Nowadays, all three strategic steps are frequently taken almost simultaneously. As soon as the location of the fire is determined, it is confined by being extinguished; however, there are still frequent occasions, usually at the fast-spreading fires, where the old rule has to be followed in sequence.

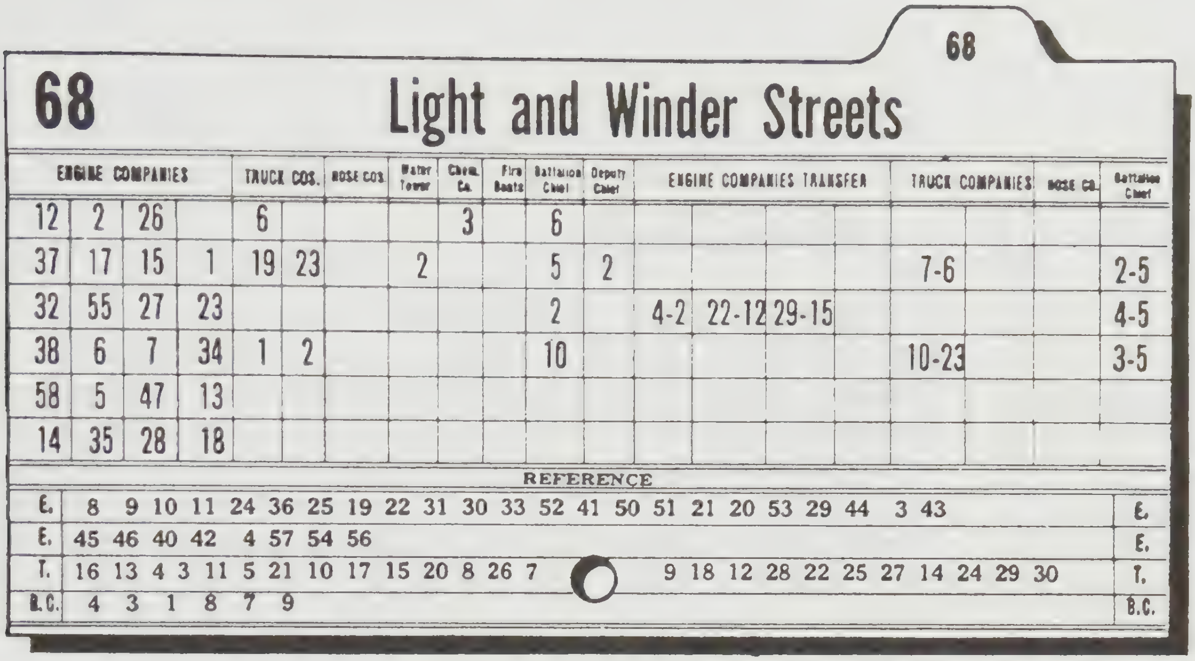
The advent of hose allowed the placement of hose lines for protecting exposed buildings, as well as attack on the fire itself. This development was a welcome change from the hooks and buckets and led to the strategy of hose line placement which prevails today. Nevertheless, in the case of large fires, the tactic of using dynamite to demolish buildings in the path of the fire was employed up until the 1920s. By that time it had been decided that this tactic did not effectively serve the purpose intended. Here we have one of several examples of a concept which looked good in theory but did not work well in practice. It is particularly interesting to note that this concept was in vogue well over a hundred years before the fire service got wise and abandoned it.

EXPANSION OF LADDER COMPANY FUNCTIONS

Hook-and-ladder companies first appeared back in colonial times, when their function was largely that of providing ladders for rescue of building occupants and application of water. As firefighting became more sophisticated, the hook-and-ladder men were assigned to force entry, open concealed spaces, and overhaul burned materials.

It was not until about 200 years after the advent of hose lines that the next major change in strategy—the theory of ventilation—was accepted. When it was, it, too, was assigned to the hook-and-ladder companies, and ventilation became one of their most important duties.

The concept of having separate engine and ladder companies (or truck companies, as they are frequently called) is widely accepted in America, but not in foreign countries. In the United States and Canada, most of the larger fire departments respond with three or four engine companies and one or two ladder companies on the first alarm (Figure 3.1), and attempt to maintain an average crew of one officer and four firefighters per unit; however, most cities under 100,000



68

68 Light and Winder Streets

Engine Companies				Truck Cos.		Hose Cos.	Water Tower	Chem. Co.	Fire Boats	Battalion Chief	Deputy Chief	Engine Companies Transfer				Truck Companies		Hose Co.	Battalion Chief
12	2	26		6				3		6									
37	17	15	1	19	23		2			5	2					7-6			2-5
32	55	27	23							2		4-2	22-12	29-15					4-5
38	6	7	34	1	2					10						10-23			3-5
58	5	47	13																
14	35	28	18																

REFERENCE

E.	8 9 10 11 24 36 25 19 22 31 30 33 52 41 50 51 21 20 53 29 44 3 43	E.
E.	45 46 40 42 4 57 54 56	E.
T.	16 13 4 3 11 5 21 10 17 15 20 8 26 7 9 18 12 28 22 25 27 14 24 29 30	T.
B.C.	4 3 1 8 7 9	B.C.

Figure 3.1. Assignment card from the Baltimore Fire Department illustrates typical alarm box response for a large American city. Companies are assigned up to a sixth alarm, including transfers (relocations).

population (and a few larger) have crews that are smaller than that. Companies with one officer and two firefighters are now fairly common.

STAFFING A COMPANY

The size of the on-duty crews in engine and ladder companies has diminished over the years, although the total number of firefighters in the company has increased. When the continuous-duty system prevailed (24 hours per day, with only one day off per month), most companies were manned by a captain, one lieutenant, and about 12 firemen. When the two-platoon system arrived after World War I, each platoon had one officer and eight firemen—an increase in total company strength but a substantial decrease in platoon strength. The practical result was very little different because under the old system two or three men were out on meal leaves, days off, and inspection or street patrol for most of the day.

When another reduction in working hours started sweeping the country after World War II, however, the practical shift strength was reduced considerably. Now, seven- and eight-firefighter companies are rare in paid fire departments.

What then, is the ideal number for a fire company? It is difficult to state authoritatively because of the many variables in the influencing factors, and because the subject has been researched but little.

STAFFING TRIALS

Some years ago, a series of staffing trials were conducted in Wisconsin. They provide at least one method of evaluating the comparative efficiency among crews varying in number. This series of experiments to provide information on staffing requirements for engine and ladder companies was conducted by the research division of the Fire Service Training Program, Wisconsin State Board of Vocational and Adult Education, with the cooperation of the West Allis and West Milwaukee Fire Departments. The problem selected was one which commonly confronts first-arriving engine and ladder companies at a fire on the fourth floor of a building.

The only factor actually measured in these trials was time. The given tasks were performed by three-, four-, five-, and six-firefighter engine companies and three, four-, five-, six-, and seven-firefighter ladder companies. This number is exclusive of the officer, who did not enter into the manual performance of the tasks.

All equipment used was of standard fire service design and the men were clad in full fire clothing. The firefighters, all experienced members of paid fire departments, were not told in advance of the trials or their purpose in order to eliminate the possibility of preparation and personal feelings influencing the results. The same men were used for all trials by their departments in order to eliminate any variation that might have been caused by differences in skills, strength, and agility. To reduce the possibility of influence caused by performance improvement due to repetition, the positions of the men in the engine company trials were changed at each trial and the trials were not in progressive order, i.e., the four-man trial was held first and the two-man trial second.

It was felt that the problems in each case were typical of a municipal fire department and that the results would provide interesting factual data for those concerned with operations of this type. The objective of the tests was to establish relative times; comparisons are more easily made when percentages rather than seconds are converted. The times of each trial were converted to percentages, with the best time taken as 100 percent and the other times converted to show their relationship.

Study 1

OBJECTIVE

To determine the relative times required to lay and advance a hose line to the fourth floor using three-, four-, five-, and six-man engine companies.

DESCRIPTION

The structure used in these trials was the drill tower of the West Milwaukee Fire Department. In each case, the hose was stretched up the inside stairway of the tower to the fourth-floor level, 44 feet above the street. The stairs are of all-metal construction, with iron banisters, and are of rectangular type with 12 right angles in the run from the street to the fourth floor. The hose used in the first four trials was double-jacket cotton rubber-lined 2½-inch-diameter fire hose, weighing approximately 65 pounds per 50-foot length. Four lengths were taken into the building. In the fifth trial, 1½-inch hose was used.

Firefighters were all from the West Milwaukee Fire Department, which is a paid, highly trained, municipal department operating in a heavy industrial area. All had been members of this department for at least five years.

EQUIPMENT

In addition to the above-mentioned hose, a conventional 1,000-gpm triple combination pumper, with a 4½-inch-diameter soft hydrant connection, was used. A stopwatch registered the times. Hose on the pumper was set up for a fire-to-hydrant lay with a 1¼-inch controllable nozzle attached to the 2½-inch hose, and a variable fog nozzle on the 1½-inch hose. In each trial, the pumper stopped at the entrance to the building, and time was started as the men began to remove the hose. Four 50-foot lengths of hose were removed and folded on shoulders by the men, who then proceeded to stretch the hose up the interior stairway to the fourth floor. In each case, sufficient hose was taken up the stairway to have 75 feet on the fourth floor. The time for stretching the hose and the time for connection to the hydrant were taken separately. Both were later included in the overall time, to reduce variable factors to a minimum. The main objective was to test the relative efficiency in taking the hose up the stairway.

The number of men in the trials included only those who were carrying hose and did not include an officer or pump operator. The time in seconds has been converted to percentages, and the shortest time taken was 100 percent. Times in these trials are for taking the hose up the stairway only and do not include driving to and connecting to the hydrant.

RESULTS
Trial 1: Four men: 100 percent
Trial 2: Three men: 134.6 percent
Trial 3: Two men: 182.6 percent

In reviewing the above times, it can be seen that it takes 34 percent more time for three men to accomplish the work that it does four men, and it takes 82 percent more time for two men to accomplish the work.

When the time used by the pumper to stretch 250 feet of hose to hydrant and the pump operator to connect up and start water is added to the above times, we get the following:

1. Pump operator making all connections unassisted
   a. Three-man company (one at pump, two stretching the hose). Time to get water to the nozzle: 160 percent
   b. Four-man company: 143 percent
   c. Five-man company: 105 percent

2. Two men connecting pumper to hydrant
   a. Four-man company: 136 percent
   b. Five-man company: 106 percent
   c. Six-man company: 100 percent

Taking the best overall time as 100 percent, the relative efficiency of each company is as follows: The six-man company would be 100 percent efficient. The five-man company would be 94.3 percent as efficient as a six-man company. The four-man company would be 73.5 percent as efficient as the six-man company. The three-man company would be 62.4 percent as efficient as the six-man company.

It is to be understood that efficiency in this case deals with time only. Other factors were not measured but could be of importance. For instance, in the trial in which two men had to take the hose up the stairway, their physical condition upon reaching the fourth floor showed signs of extreme fatigue. It would not be advisable for men in this condition to enter a smoke-filled area.

An additional trial was run using 1½-inch hose instead of 2½-inch. The time to take it up the stairway was considerably less than the time needed with the 2½-inch hose. In this trial, three men took the 1½-inch hose up the stairs. Using their time as 100 percent, the relationship with the 2½-inch hose lays is as follows:

1. 1½-inch hose, three men: 100 percent
2. 2½-inch hose, three men: 146 percent
3. 2½-inch hose, four men: 106 percent

Some of the observations made during the above trials were: With the method employed, and one man working alone at the pump and hydrant in each trial, the nozzle was at the fourth floor before the man at the pump could start water. With two men making the connections at the hydrant, the time to get water to the nozzle was considerably less, but only in the case when two men took the hose up the stairway was the pump operator able to start water before the nozzle reached the fourth floor. Therefore, it can be seen that three or four men can stretch 200 feet of hose up a stairway to the fourth floor before water can be started, even when the pumper has to travel to the hydrant after the hose has been dropped, and when two men make the hydrant hookup.

Considering both time and manpower, the most efficient operation was that involving a five-man company when three men took the hose up the stairs and two men made the connection to the hydrant.

Study 2

OBJECTIVE

To determine the time required for a ladder or truck company to perform the following tasks:

1. Raise aerial ladder to roof of five-story building and open scuttle cover on roof
2. Open two windows on the fifth floor and four windows on the fourth floor
3. Open one window on the ground floor and open the door from the inside on the ground floor

DESCRIPTION

Tasks were performed by members of the West Allis Fire Department. West Allis is a heavily industrial community with a population of about 50,000. The firemen are highly trained, and the service of the men in these experiments ranged from three to 12 years. The ladder used was a 100-foot hydraulically operated metal ladder, tractor-trailer type.

The hypothetical fire problem given was that:

1. There was a fire on the fourth floor.
2. The building was to be ventilated at the roof, fifth floor, and fourth floor.
3. A 35-foot extension ladder was to be raised to a fourth-floor window, if three men were available. This ladder is considered to be a three-man ladder.
4. Forcible entry was needed. Each man was to carry either an ax, a Kelly tool or a halligan tool.
   a. On the roof, a locked scuttle-hole cover had to be opened.
   b. On the fourth floor, one double-hung window had to be forced to get inside in order to open the other three windows.
   c. On the ground floor, one double-hung window had to be forced.

The times given for the several trials are for completion of all these tasks. Times are compared on a percentage basis, with the best time taken as 100 percent. In each trial, time was started when the truck came to a stop at a point opposite and 30 feet away from the building entrance.

TRIAL 1

To establish the time required for two laddermen and the driver to do the problem:

One man went to the roof to open the scuttle-hole cover and to ventilate the fifth and fourth floors. The second man forced a first-floor window and opened the door from the inside (after roof opening), then proceeded up the inside stairway with the engine company and assisted his partner with ventilation. The 35-foot ladder was not raised because only two men were available.

Time: 168 percent

TRIAL 2

To establish the time for three laddermen and the driver to do the problem:

All men prepared the aerial for raising and, while the ladder was going up, three men raised the 35-foot ladder to the fourth-floor window. One man then went to the roof to open the scuttle-hole cover and ventilated the fifth and fourth floors. The other two men forced the first-floor window, opened the door, and both accompanied the engine crew to the fire and assisted in ventilation.

Time: 150 percent

TRIAL 3

To establish the time required for four laddermen and the driver to do the problem:

Three men raised the 35-foot ladder and assisted in ventilation after one man forced the first-floor window and opened the door. One man went to the roof to open the scuttle-hole cover and ventilate the fifth and fourth floors.

Time: 114 percent

TRIAL 4

To establish the time required for five laddermen and the driver to do the problem:

Three men raised the 35-foot ladder and assisted in ventilation of the upper floors using the inside stairway. One man went to the roof to open the scuttle-hole cover, and ventilate the fifth and fourth floors. One man was sent to force the first-floor window and open the door after roof ventilation was completed.

Time: 107 percent

TRIAL 5

To establish the time required for six laddermen and the driver to do the problem:

Three men raised the 35-foot ladder and assisted in ventilation, using the inside stairway. Two men went to the roof to open the scuttle-hole cover and ventilate the fifth and fourth floors. One man forced the first-floor window, opened the door, and assisted in ventilation.

Time: 100 percent

The same man was used for the same duties on each operation. For instance, the same man went to the roof and opened the scuttle-hole cover five times. The same man forced the first-floor window each time, and the same men raised the 35-foot ladder to the same window in each operation.

The man who opened the scuttle-hole cover climbed down from the roof by the cat ladder to the fifth-floor fire escape landing, where he opened the door and two windows. He left by the same door and came down the fire escape to force a fourth-floor window and went inside to open the three other windows.

So that fatigue would not affect the time, the men were required to rest ten minutes between operations.

It is obvious that the aerial ladder raising operation slows up the entire procedure. If a fire escape is available, the first man or men should use it to gain access to the roof, while the ladder is being raised. In a separate test, one man was sent to the roof once by way of the fire escape and once by way of the aerial ladder. He arrived at the roof in much less time when he went by way of the fire escape, even though this time included removing a 14-foot extension ladder from the truck and raising it to the lowest fire escape balcony unassisted. The times were:

Fire escape: 100 percent
Aerial ladder: 144 percent

We are not attempting to come to any definite conclusions on the basis of these trials alone, but we feel that the information compiled is of value in establishing comparisons of the time factor. It is emphasized that relative efficiency in these trials was measured only on the basis of time. There are other factors to be considered, and it should be remembered that other methods of firefighting may be employed effectively on the same type of problem.

PERSONNEL ON FIRST ALARM

More and more, it is being recognized that the important personnel consideration is the total number of firefighters responding on the first alarm, rather than the total number of units. A first-alarm force of 12 can do the ladder and engine company work which would be adequate for a fire involving up to 8,000 square feet of a building. In some cities, special squads are used to augment the personnel of engine and ladder companies. They respond on a vehicle which is not designed for firefighting but merely gets them to the fire rapidly so they can use the equipment of the engine and ladder companies present. It is not a new concept, by any means. Milwaukee had such squads as far back as 1912. New York City used them during World War II to offset the personnel shortage caused by the war. Milwaukee gave up these squads after several years and so did New York. The squad usually consists of a lieutenant and five firefighters who respond with no equipment other than their breathing apparatus and are used as the chief in charge of the fire sees fit.

The squads cover a territory on the first alarm that is larger than that of an engine or ladder company. They also respond on second alarms over a very wide area. How often they are used is indicated by the following table, which shows that they do a lot of running but have a relatively low percentage of fire duty when compared to neighboring engine and ladder companies. In the Brownsville section of

Brooklyn, Squad 4 responded over a greater area than Engine Company 283 and Ladder Company 120. These units accumulated the following totals in one year:

	Runs	*Workers*
Squad 4	8,952	2,765
Engine Company 283	6,900	3,981
Ladder Company 120	8,013	5,282

ESTABLISHMENT OF RESCUE COMPANIES

The rescue company came into being in New York City in 1915, and the concept soon spread around the country. Such companies are given special equipment and training to deal with emergencies other than fire, such as gas leaks, train wrecks, serious automobile or construction accidents, and the like. The term "rescue" is much abused and vaguely used. It is quite common now in some parts of the United States to call an ambulance a "rescue squad." A better term is needed. Routine transportation of invalid persons should not be termed "rescue."

In some cities, rescue companies have become first-aid squads, taking care of injured people and providing oxygen and therapy to persons with heart attacks and other seizures. Several fire departments are now running a paramedic service with the ability to take electrocardiograms and transmit them by radio to a hospital, and to operate electronic defibrillators. Such services are not within the scope of this book but are mentioned here because the personnel needs of services such as those described can affect the application of firefighting strategy. Several fire departments are giving exemplary ambulance service and reaping a harvest of good will. Others, strained to get enough crews for fire duty, are hard-pressed to provide an ambulance service.

SALVAGE

Salvage is the portion of fire operations that has undergone the greatest strategic change. Back in colonial times, salvage or "bag" companies, as they were then called, were created to minimize loss by removing furniture and goods from a building on fire—or threatened by fire. Over the years, this work developed as a function provided by the fire insurance underwriters who maintained salvage units in many cities. These companies were not part of the fire department; their apparatus and stations belonged to the local underwriters and the personnel were employed by them. Known as "fire patrols" or "salvage corps," they responded in trucks resembling fire apparatus except that nearly all the equipment carried was designed to protect premises from water rather than fire. The equipment consisted of canvas tarpaulins to cover furniture and stock, sawdust to soak up or channel water, and squeegees and other devices to remove water. Additional equipment included shovels, brooms, and materials and tools to cover holes in roofs or broken windows.

New York is the only city in the United States where the insurance underwriters still provide this service. Elsewhere the function of salvage has been abandoned completely or taken over by the fire department. Those fire departments which do provide salvage work now do it with either engine or ladder company personnel. Hardly any maintain separate salvage companies. Montreal, Canada, combined salvage and rescue into one unit and had several such companies. (These units were all taken out of service by 1984.) One responded on almost every first alarm to provide whichever of these two services (sometimes both) was needed. This procedure seemed to have the merit of assuring that the salvage duties were carried out promptly. Usually when they were left to engine and ladder companies—which were probably short-handed to begin with—they were placed far down in the priority sequence at fires.

The passing of the salvage companies left a gap which has not been fully filled in most places. Salvage men were specialists, well trained in the job, and with the sole duty of salvage. Often they would have their canvas covers spread over the contents of the floor below the fire before the first water trickled down from above. The fact that they were discontinued doesn't mean that their duties were found to be unimportant. Rather, they are gone because the insurance companies decided that their cost was more than they wished to pay.

INFLUENCE ON THE FIRE SERVICE BY THE INSURANCE INDUSTRY

Probably the biggest single influence on the fire service in the United States has been the fire insurance industry. The stock fire insurance companies, through the National Board of Fire Underwriters, shaped the structure of the fire service into what it is today. Since 1915, the grading schedule for towns and cities has set forth criteria for fire defense. Although they are not mandatory, almost every fire chief tries to abide by them in order to earn the prize of a good grading; however, most municipal officials will not spend the money needed to earn a top grading and, consequently, there aren't many Class 1 fire departments under the grading schedule. Nevertheless, these standards have given the fire chief a strong lever in trying to improve fire protection.

The insurance interests are largely responsible for the high degree of uniformity existing in the American fire service today. Back in 1873, the Home Insurance Company hired a former New York City battalion chief, William Brandon, whom they sent around the country to rebuild the fire departments of major cities. The foundation laid then formed the basis of our present system and was probably the main reason for uniformity in strategy and tactics. Chief Brandon worked with the fire departments of Baltimore, Boston, Buffalo, Chicago, Cincinnati, Cleveland, Detroit, Indianapolis, Louisville, Memphis, Milwaukee, Nashville, Philadelphia, Providence, Rochester, St. Louis, Syracuse, and others.

In conjunction with the National Fire Protection Association and the International Association of Fire Chiefs, the underwriters developed apparatus standards which are followed almost without exception. They are described in *Specifications for Motor Fire Apparatus*, published by the NFPA.

The principal concern of the fire insurance interests was to prevent large conflagrations. The grading schedule was designed to evaluate the general conflagration vulnerability of a city and the fire department's capability of keeping a fire from becoming a widespread conflagration. From the earliest days of this nation until the early 1920s, fearsome conflagrations—burning several city blocks—were relatively frequent.

It is not easy to determine why the situation has changed so much. Perhaps it is a combination of improvements such as better water supplies, bigger pumping engines, and better trained fire departments, but building laws and construction must also be important factors. During the civil strife of the late 1960s, several cities were subjected to fire situations far beyond the capability of the fire department, yet none of the hundreds of ignitions developed into a conflagration (Figure 3.2). In some cases, the fire department was unable to reach a fire for several hours, and yet fire did not jump across the surrounding streets.

The diminishing fear of large-scale conflagrations is becoming noticeable, both in the insurance industry and the fire service. Fire departments now seem to be gearing their personnel and responses for the average rather than the ultimate. Both economic pressures and an increased number of alarms have brought some innovations.

PROGRESS IN FIREFIGHTING

The past 60 years have not seen much advancement either in fire department armament or technique. Little was introduced to extinguish a fire in a building other than the elevating platform, the

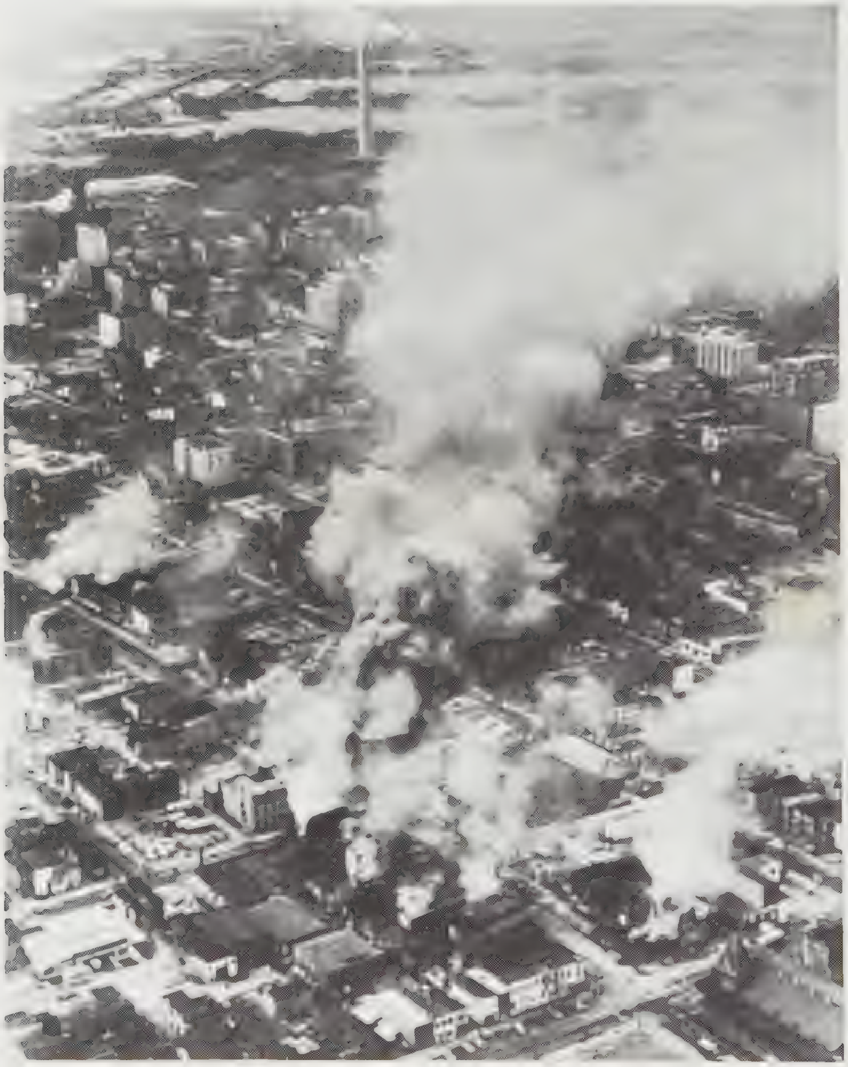


Figure 3.2. Washington burning. Civil disturbances in American cities brought multiple fires that were far beyond the capability of fire departments, yet none turned into conflagrations.

super pumper, and high-expansion foam. Of these three, the first two were valuable improvements or enlargements of existing equipment. Only the high-expansion foam is a new concept. The greatest progress has been made in specialized equipment that uses such agents as aqueous film-forming foam, which is somewhat more effective on flammable-liquid fires than the chemical foam of 60 years ago. The various present-day dry chemicals and oxygen-diluting chemicals, such as the halons, are better than their ancestors, which were used at the turn of the century.

While it is true that these are improvements, they do not give the fire service new techniques. If a fire chief of 100 years ago could be brought back to life and put in charge of a fire today, he would be fairly well at home. His methods and orders would be understood, because they would be the same as those that would be given by his present-day successor. He would find slightly more powerful artillery, but a smaller infantry. His strategy and tactics would have to be altered only to allow for those differences.

If there has been a truly significant advance in firefighting in the twentieth century, it has been in the field of training. Not much more is known now than was known 75 years ago, but it is known by far more people. The knowledge that was once exclusively held by a few is now available to many.

There are many similarities between the tactics and strategy employed by foreign fire departments and those of the United States and Canada. There are, however, also many differences. American fire stations are much closer together than those in Europe. Most continental cities average one station per 100,000 population, as compared to the American average of one to 10,000. Europeans, however, have a much bigger complement of firefighters and apparatus in their stations than we do. The first-alarm response in a major European city would bring almost as much in personnel and equipment as would that in an American city of similar size, but the total shift strength and total staffing is usually far less. European cities usually have bigger police departments but much smaller fire departments than their American counterparts. Some of the Mexican cities just south of the United States border are larger than the neighboring city on the American side, but have fire departments only a fraction as large. Another source of amazement to Americans is the limited water supply in large South American cities. Water is conveyed to fires by fire department tank trucks in some cities with as much as a million in population.

EUROPEAN METHODS

The state of the art in European firefighting has progressed at about the same as it has here. All of the types of apparatus and equipment which we have are also found in Europe—in fact, several of them originated there and were later brought to this country. Europeans put great emphasis on the use of breathing apparatus. They have been using self-contained oxygen or air units for almost 100 years. The Scandinavian fire departments have specialists called "smoke divers" who do all the interior firefighting with breathing apparatus in heavy smoke conditions. These firefighters are specially selected and trained and are not allowed to continue this special work after reaching the age of 35. Nearly all the larger cities have at least one such squad, and they ride to all fires in their own vehicle, which carries little more than firefighters and their breathing equipment. The squad usually consists of an officer and six firefighters.

Interior attack is stressed throughout Europe, usually with less volume of water than would be used in America. Initial attack lines are about 1¼ inches in diameter, flowing about 40 U.S. gallons per minute. Even the larger lines have smaller nozzles than would be used in the United States. Most European fire departments carry their hydrants on their pumpers and fit them into a connection found below street level at the scene of the fire (Figure 3.3). Nearly all of

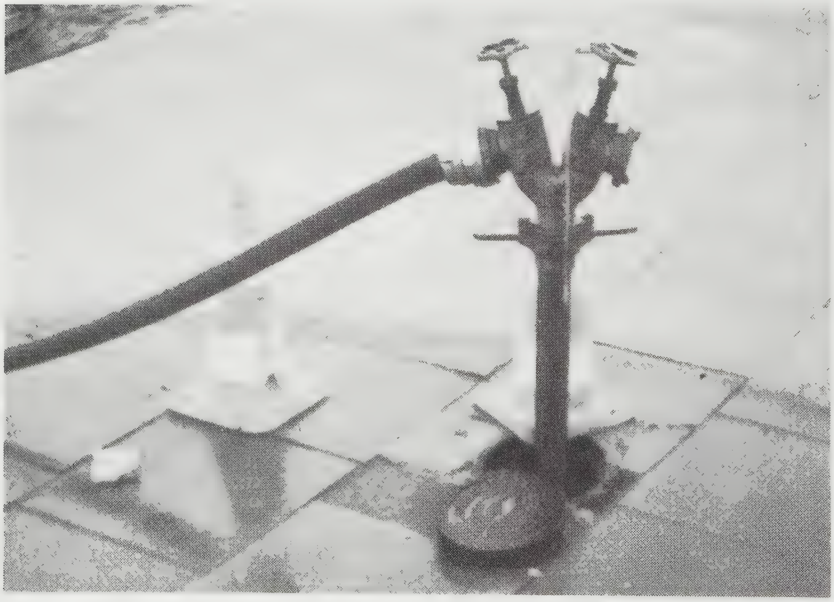


Figure 3.3. *This German hydrant is typical of the European type that is carried on apparatus. At the scene of the fire, the hydrant is inserted into a connection below street level.*

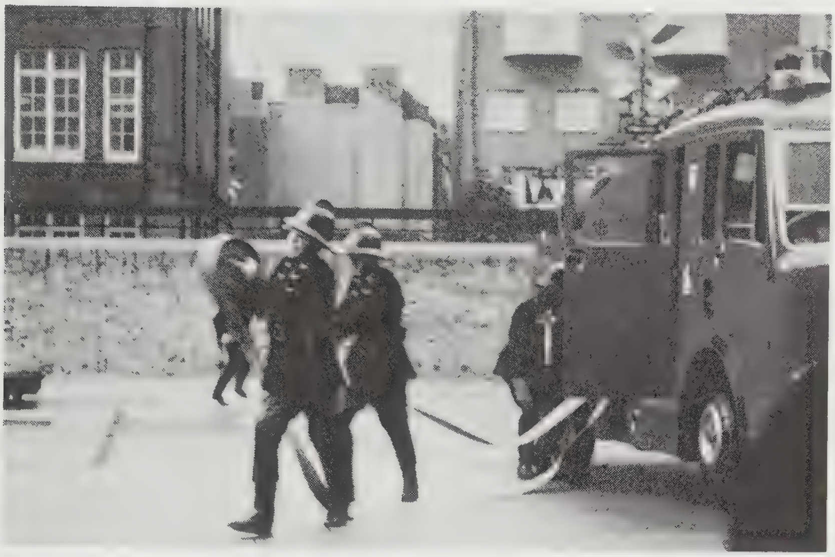


Figure 3.4. British hose lay is fast for short distances. Each firefighter carries a 100-feet roll, which he unrolls as he runs toward the fire. The next man connects his roll to the first one and lays out from there. Snap couplings are used.

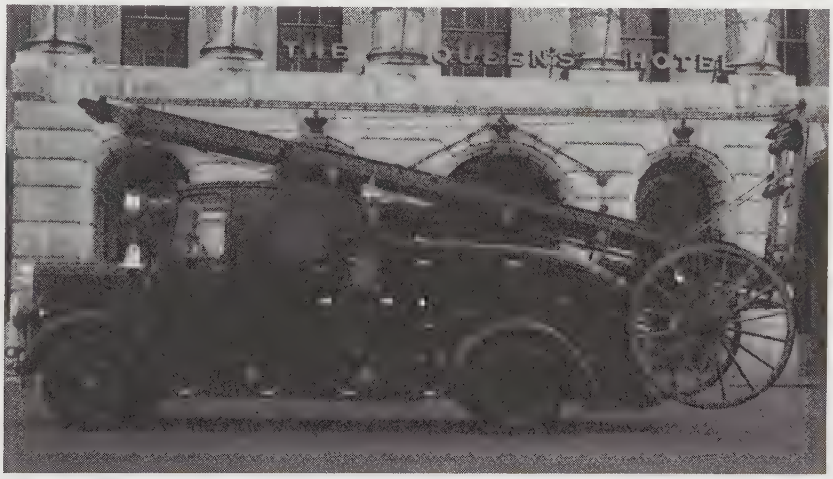


Figure 3.5. The combination pump-escape is a European apparatus which carries a wheeled ladder that can be quickly detached at a fire and rolled into position. It provides a stable ladder up to 40 feet in length. The Swiss have a similar ladder that is 75 feet long.

them use quick-connect couplings, which are the same at both ends of the hose. In the British Isles, it is the custom to carry hose in rolls 100 feet long, which are coupled after arrival at the fire (Figure 3.4).

One major difference in European strategy is that the aerial ladder truck is not staffed by a ladder company and is not equipped with ground ladders, tools, or other equipment. It is merely an aerial ladder on wheels and nothing more. The pump-escape, an extension ladder mounted on two large wheels, is carried on a pumper and can be released and wheeled into position quickly by two firefighters. It can be wheeled into alleys and other narrow places to provide a very stable ladder up to 40 feet in height (Figure 3.5).

There seems to be a common belief in this country that building construction in foreign countries is so different from ours that they need less fire protection. While it is true that they don't have many wooden exteriors, the majority of the buildings and contents are quite susceptible to fire.

Foreign and American firefighting developed independently, so it is natural that some differences would exist. The fact that the theory and practice don't differ to a greater extent indicates that better ways are yet to be discovered.

NOTE

1. Gratz, David B.: *Strategic Planning—A Way to Maintain Control.* New York, NY: Fire Engineering, September 1971.

4

Firefighting Strategy

A GENERAL STRATEGIC plan for firefighting can be arrived at through consideration of the following basic factors: (1) What is to be done? (2) What is needed to do it? and (3) Who is to do it?

Item 1 includes all duties performed from arrival to departure, i.e., search and rescue; locating, confining, and extinguishing the fire; and all the work incidental to these activities, which will be described in later chapters.

Item 2 is the key to the situation and, fortunately, a formula, provided by Keith Royer and F.W. Nelson[1] of Iowa State University, enables the fire officer to answer the question. The formula is called "the ideal rate of flow." It is easily arrived at and is reasonably accurate for all practical purposes at the most commonly encountered fires. Simply stated, it says:

$$\frac{V}{100} = gpm$$

V is the volume of the fire container in cubic feet, easily determined by multiplying length by width by height, *gpm* is rate of flow, and 100 is a constant factor.

For example, a bedroom measures 10 × 12 feet with an eight-foot-high ceiling—a volume of 960 cubic feet, which, divided by 100, gives an ideal rate of flow of 9.6 gallons per minute. Thus, it can be determined that a flow of 10 gpm will control a fire in that bedroom. In fact, the formula establishes this ideal rate of flow as being within the capacity of a booster line at a fire of those dimensions.

If we change the situation to a dwelling fire involving one whole story measuring 30 × 40 × 8 feet, we find that the volume of 9,600 cubic feet calls for 96 gpm, barely within the capability of one 1½-inch line (depending on nozzle setting and pressure). A further change to a store 20 × 90 × 10 feet would require 180 gpm, or, freely translated, one 2½-inch line with at least a 1-inch tip, or two 1½-inch lines of at least 95 gpm each.

One further example to amplify the ideal-rate-of-flow theory is that of a fire in a four-story building measuring 50 × 100 feet with ten-foot-high ceilings. If the fire involves only one floor, it will call for a flow of 50 × 100 × 10 = 50,000 ÷ 100, or 500 gpm. If any other story becomes involved, however, the amount of water needed should be increased accordingly, along with an increase in personnel and equipment.

There have been attempts to modify this theory both for occupancy and for percentage of area involved. They are not only unnecessary complications but erroneous. The formula should be left alone.

Personnel utilization is getting closer scrutiny because of economic restraints. Those persons responsible for fire department fiscal allotments are looking hard at personnel quota needs in fire departments with salaried firefighters. In some cases, personnel quotas have been reduced arbitrarily to meet budget allowances. The fire department is forced to operate with a reduced work force. What are the practical limits and how does the theoretical relate to the actual when the personnel to gpm ratios are compared?

Theoretically, at a one-alarm fire, we could get the following:

Units	*Firefighters*	*gpm*	*Average gpm per Firefighter*
3 Engines	5	100	20
	5	220	44
	5	250	50
1 Truck	5		
1 Chief	1		
1 Aide	1		
Totals	22	570	26

Then, to the gpms on the first alarm we must add the gpms provided by the units on each additional alarm as indicated:

SECOND-ALARM (including first-alarm units)

Units	*Firefighters*	*gpm*	*Average gpm per Firefighter*
6 Engines	30	1,500	50
3 Trucks	15		
2 Chiefs	2		
2 Aides	2		
Totals	49	1,500	30

THIRD-ALARM (including first- and second-alarm units)

Units	*Firefighters*	*gpm*	*Average gpm per Firefighter*
9 Engines	45	3,500	80
4 Trucks	20		
3 Chiefs	3		
3 Aides	3		
Totals	71	3,500	50

In actual practice—according to a survey of several fires—the theoretical figures given above are over three times the average gpm per firefighter for the first alarm and just about the same as actual for the second and third alarms. If all three examples are averaged, we get about 41 gpm per firefighter, which could be reasonably rounded out to 50 gpm in most cases. Thus we have arrived at a figure which appears to be realistic in practice as well as theory, but it does raise questions as to what everyone at the fire is doing when such a low average is obtained. (All of the figures are based on four firefighters and one officer per company and can be adjusted accordingly.)

Another question arises when the capacity of all the pumping engines is compared to water delivery, for instance, if all are 1,000 gpm pumpers.

	Pumpers	*Average Delivery gpm*	*% of Total Capacity*
First Alarm	3	190	19
Second Alarm	6	250	25
Third Alarm	9	433	43

When it is recognized that the third alarm will probably require longer hose lays and, therefore, some pumpers will have to operate at less than capacity, it can be said that the pumping effort is getting close to efficiency as the size of the operation increases. The gpm per firefighter ratio also increases with the size of the operation.

A recent study of 250 large fires disclosed that the average number of firefighters present represented one firefighter per 80 gpm of water discharged. There was one pumper present for every 500 gpm pumped. The number of firefighters included officers, aides, and pump operators as well as all other firefighters, regardless of the duties they were performing. In short, the total personnel divided into the gallons per minute gave a number slightly less than 80. For the sake of simple and rapid figuring, it would be fairly safe to assume that a personnel figure of one firefighter per 50 gpm of the ideal rate of flow would establish the minimum number of firefighters necessary, and that one pumper for every 500 gpm required would be adequate. Of course, this statistic doesn't mean that every pumper would be discharging 500 gpm. In actual practice, some discharged more and some less, but the average at 250 large fires was 500 gpm per pumper.

This water requirement method (ideal rate of flow) could be used to determine how many firefighters and how many pumpers are needed. This method could be applied in pre-fire planning, as well as at the scene of the fire. In pre-fire planning, it could show how much mutual aid might be needed and if the water supply is sufficient.

At the fire, this ideal rate of flow will help the officer in charge to determine his needs for water, apparatus, and personnel. This guide is probably the best instrument given to the fire officer for determination of these requirements. We have heard of various rules of thumb such as: "I look in the front, then the back and if when I return to the front, the color of the smoke hasn't changed, I send a second alarm." The ideal rate of flow, however, enables the fire officer to determine the requirements on a scientific basis, rather than on guesses or instincts. After making the estimate, the officer will know how many pumpers, how many firefighters, and how many gallons per minute are needed and can call for them in a reasoned and orderly fashion.

Unfortunately, a good guide for the number of ladder companies and other units is not easy to come by. A rule of thumb is one ladder company for every two engine companies, but the need can vary with the situation. Ladder companies would not be of much value at some kinds of fire unless they were assigned duties beyond their usual ones, such as stretching hose lines. The normal one to two ladder-engine ratio is based upon ordinary building fires. As a rule, the larger the fire, the less need for ladder company work. Certain fires, such as outdoor fires, do not require much of the skills and equipment of the ladder units.

Briefly stated, then, the ideal-rate-of-flow formula can be applied to determine the following needs:

Water	$\text{gpm} = \dfrac{L \times W \times H}{100}$
Personnel	$\text{Firefighters} = \dfrac{\text{gpm}}{50}$
Pumpers	$\text{Pumpers} = \dfrac{\text{gpm}}{500}$

This system has been tried and found satisfactory many times at test fires, including one at Waukesha, Wisconsin, where 50,000 pounds of scrap wood were burning in a room with a volume of almost 84,000 cubic feet. Actually, the only water system available could supply no more than 750 gpm, but this amount quickly controlled the fire in three tests. In the first two tests, the water was applied through eight 1½-inch lines at 94 gpm each. In the third test, the same amount was applied through three 2½-inch lines. In the first two tests, the fire went from complete involvement to knockdown in 23 seconds. The third trial took longer (47 seconds) to achieve the same result, probably because the fire was hotter (as shown by a recording pyrometer), and there were fewer vantage points (three hose lines versus eight).

PERSONNEL REQUIREMENTS

It can be argued that the figure of one firefighter per every 50 gpm needed will not always supply adequate personnel. This is probably so in many cases, but the extreme conditions that arose in some cities as a result of civil disturbances in the late 60s showed clearly what a few firefighters can do when there is no assistance forthcoming. The above-mentioned test in Wisconsin proved that six men operating three 2½-inch hose lines with a 1⅛-inch nozzle on each could darken a fire involving 50,000 pounds of wood in an 80,000-cubic-foot room in 47 seconds.

In normal circumstances, however, more firefighters than those given by the formula would be desirable. Therefore the formula should be taken as an indicator of *minimum* requirements. If that much water is not within the capacity of the pumpers present, more pumpers are needed. If the number of firefighters present is not as much as required by the formula, more firefighters should be called. Another option of Item 2 (What is needed to do it?) would be the need for special apparatus and equipment. For instance, in establishing the needs for a fire involving bulk oil storage, quantities of foam and the equipment to apply it would be strategic requirements.

Item 3 asks, "Who is to do it? Usually, the answer is the officers and firefighters of the first-alarm companies, but sometimes there are special requirements that they can't meet, and sometimes the fire is of such size that they are not able to cope with it. In each of these cases, the officer in charge must decide who else is going to perform the needed work and take steps to call them. Fortunately, most strategic requirements can be decided upon before the fire occurs. Pre-fire planning using the formulas given in this chapter can give the officer the necessary answers and, furthermore, it can make them available for immediate use upon arrival at the fire.

Strategy is not limited to consideration of water, apparatus and personnel needs. It must also consider how to employ firefighters to achieve the desired results in the most efficient manner. It is in this area that many problems arise. Understaffed engine companies probably account for the greatest deficiency. I once witnessed a fifth-alarm fire in a city that manned its engine companies with an officer, a pump operator, and one fireman. Each of the five alarms brought three such engine companies to the fire, supplying a total of 15 officers, 15 pump operators, and 15 firemen. An optimistic assumption would allow that the 15 firemen could operate seven 2½-inch hose lines. Then we would have the following picture: Fifteen engine company officers supervising the operation of seven hose streams which were supplied by the three pumpers nearest to the fire, while the other 12 pump operators stood by listening to the fire reports on their radios. Thus, out of the 45 officers and men who responded with the 15 pumpers, only 22—less than half—were doing necessary work, and of the 15 pumping engines, three were used.

Many fire departments make the strategic error of gearing for the usual and not the potential. Of course, smaller communities cannot afford the means of properly combating the potential by themselves. Nevertheless, if they had an adequate mutual-aid plan they would probably be able to command as much equipment and personnel as would be available at a fifth alarm in any of our large cities. Yet we find few plans that would provide this much, even in towns with hazards big enough to require at least that amount of firefighters and apparatus.

A government survey in a midwestern state disclosed that few mutual-aid agreements provided adequately for the largest fire potential in the communities studied. The report concluded that this situation occurred because most of the fire chiefs thought only in the light of what they had already experienced, and that the maximum number of companies they specified to respond to them on mutual aid was usually equal to the largest number they had ever supervised.

The amount of companies, personnel, and special equipment specified should be based on reasonable pre-fire planning, such as the water requirement method, rather than what is needed at just the average fire.

The personnel problem is most acute in small, paid departments, but many suburban communities suffer from a shortage of volunteers during business hours. Some of these departments have either a feast or a famine, depending upon the time of the alarm. They occasionally have fires where no officer is present. This problem should be considered in strategic planning. Availability should be an important factor in officer selection, but, surprisingly, it is not always considered. I have visited fire departments where the chief and both assistant chiefs worked in other towns and were not available for fires during business hours.

Also important in strategic planning in the volunteer department is a method to ensure that a certain number of firefighters will be in town at all times, including hunting seasons, athletic contests, or other events which could draw members of the department elsewhere.

A reserve firefighting force, such as the national guard is to the army, is an alternative to a mutual-aid plan. Isolated cities with inadequate personnel could back them with a well-trained auxiliary force. The problem in most small paid departments is not the lack of equipment as much as lack of personnel. They have the pumping capacity to apply three times the water that their personnel can handle and four times as many ladders as they can raise in a reasonable time. Auxiliaries should be well trained, however, and used only at other than routine fires. This system would be highly desirable in places where mutual aid is distant or weak.

We live in a world of compromise, and the fire service is a prime example of this condition. But if the fire service can't obtain the ideal because of economic constraints, it should concentrate on fighting for what is really essential.

APPARATUS RESPONSE TIME

The close proximity of fire stations in the average American city is due for re-examination. Response distances are often based on a grading schedule which was drawn up when fire trucks were pulled by horses, and in which the response distances have been increased but little since it was first written. Although it can be argued that heavy vehicular traffic now slows responses, and that response distances should be just as short today as in the horse-drawn era, this problem would hold true only in peak traffic hours. Tests have shown repeatedly that modern fire apparatus in many cities can maintain an average road speed of 30 mph per run while responding, which is much faster than horses could pull heavy fire apparatus, especially on runs of a mile or more.

The maximum permissible response time has never been determined scientifically, and there is little statistical support for a definite limit. The answer lies somewhere between having a fire station on every corner and having only one in the whole city. But just what is it? What is the actual effect of distance on fire damage? In one city, the fire department has been making a study of the relationship of response distance to damage in kitchen fires. Kitchens were chosen because they are similar in size, nature, amount, and type of use, and because kitchen fires are relatively frequent. No significant pattern has emerged.

NEED FOR COMMUNICATIONS

A system of communication that assures accurate and prompt response to alarms is quite essential, as is a good system for communicating at the fireground. Provision should be made for adequate substitution if normal electric or telephone service fails. A radio communication system is a must, and it should be well regulated, with written rules to gain maximum efficiency, reduce misunderstanding, and eliminate unnecessary radio traffic (Figure 4.1).

Codes, however popular, can lead to mistakes, which sometimes have serious effects. Prior to the adoption of radio, the fire service had to depend upon coded signals tapped on a telegraph key. Now that voice communication in easily understood English can be used, many fire departments have reverted to code. Codes often take longer to speak than the phrases they represent, are sometimes difficult to remember, and often lead to errors which would not occur if everyday English were used. The "10-signals" originated in police departments

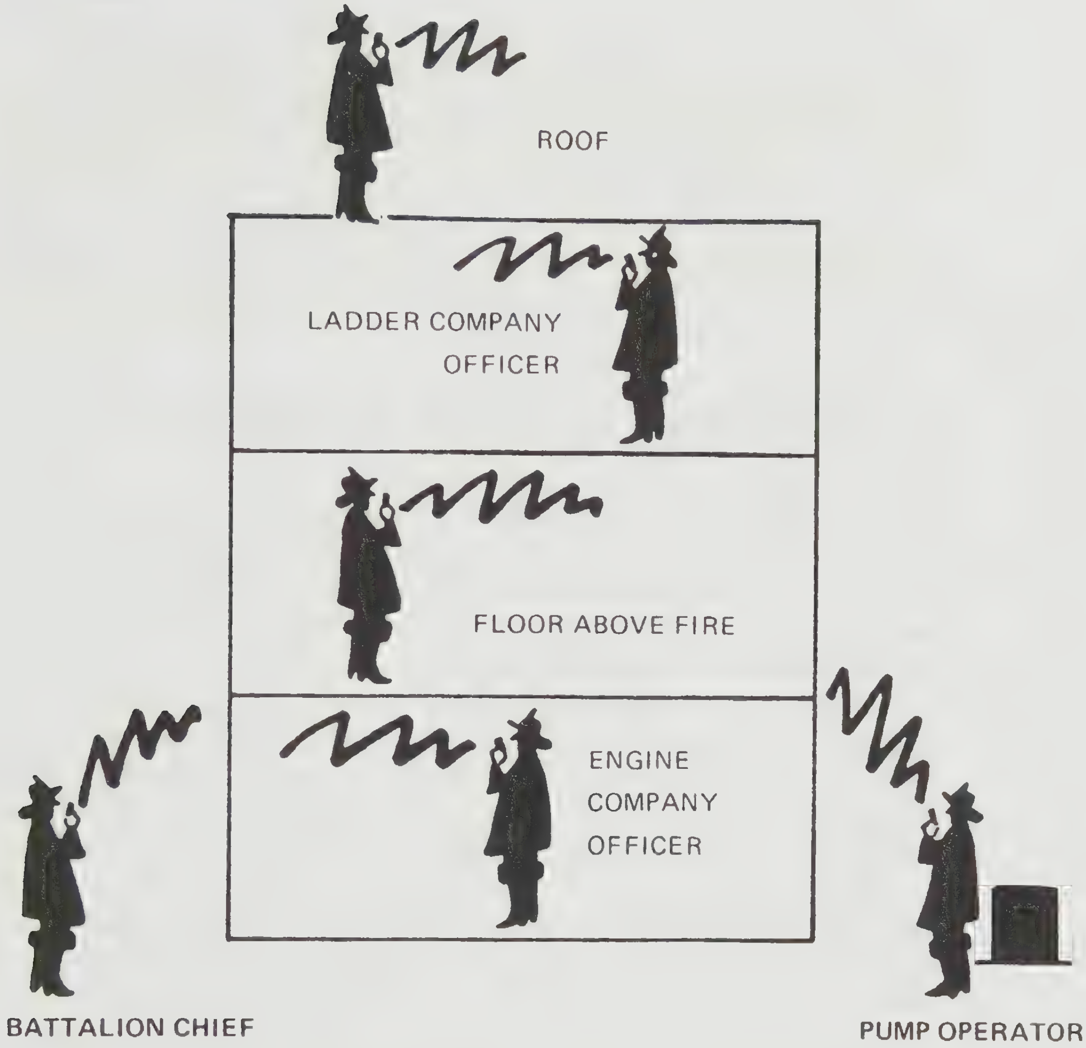

ROOF
LADDER COMPANY OFFICER
FLOOR ABOVE FIRE
ENGINE COMPANY OFFICER
BATTALION CHIEF
PUMP OPERATOR

Figure 4.1. *A pocket-sized transceiver permits a company officer within a building or out of sight of the command position to be in constant communication with chiefs in charge. An added advantage is that an engine company officer can be in touch with the pump operator to regulate flow from the nozzle.*

where there may be some need to keep communications disguised; they are of dubious value in the fire service.

Radio communications should be short, to the point, and clearly stated. Portable sets at the fire scene should be carefully distributed to assure the greatest benefit. New York City equips each engine company with two pocket-size transceivers and ladder companies with two each in average districts and three each in high-hazard areas. In the engine companies, one set is carried by the officer, the other by the pump operator. This arrangement not only allows the officer to order changes in pressure but, more important, gives him a direct and immediate link to someone in the street if trouble develops. In the ladder companies with two sets, one is carried by the officer, the other by the individual assigned to the roof of the fire building. In those companies having a third set, it is carried by the firefighter designated to go to the floor above the fire.

The probability of simultaneous fires close enough to be within radio range of each other requires multi-channel transceivers to eliminate radio interference, which might cause confusion. Care should be taken to select a channel not already in use within range.

CHAIN OF COMMAND AT FIRES

A prime strategic consideration is a system for the delegation of command responsibilities and duties at the fireground to assure that nothing of importance is overlooked, that operational efficiency is maintained at a high level, and that personnel and equipment are properly utilized and safety is observed.

In the course of fire service development, a pattern of duties has emerged, as well as a fire department hierarchy. Titles and duties vary but little from one part of the country to another. The major differences are in titles rather than in duties at the fireground. Some departments call the second in command an "assistant chief," while others use the term "deputy chief." Some fire departments skip the rank of lieutenant and have all the company officers designated captains. To allow for local terminology differences, perhaps we should drop the military titles here and for the moment refer to the officers in question by their ranking at the fire scene. Another justification for this approach is the fact that in some cases all the ranks may not be present at a major fire. Therefore the terms, "first in command," "second in command," "company officer," and so on are used in this chapter rather than the designated title within the department. The duties and positions of the chief officers will be discussed here. Those of the company officers—engine and ladder—will be discussed in other chapters. The first in command or chief in charge is also called the "incident commander."

Naturally, the first in command should direct the overall operations and relate department policy and established strategy to the situation at hand. This officer should choose the tactics, direct, control, and coordinate the activities of all personnel and equipment.

Usually at a major fire, the incident commander will do this through an established chain of subordinates, each of whom has definitely delegated responsibilities. Therefore, the chief duties of the first in command are the overall direction and the coordination of the activities being supervised by those officers reporting directly to him.

It is axiomatic that the chain of command be a two-way street. Orders should flow downward, and information should flow upward. The decisions of the officer in charge have to be based largely on what he is told. His personal view of a large fire is limited to one or two fronts, so he must depend on other officers to inform him of the situation on other fronts. His action plan must be based on the information he has received.

ESTABLISHMENT OF A COMMAND POST

The question often arises as to where the incident commander should station himself. One school of thought believes that officer should establish and never leave a command post; another thinks that he should be able to roam and thus make a better diagnosis of the fire situation by getting several viewpoints. The latter theory has received additional support since portable radios have become available for fireground use, enabling the first in command to maintain contact with the command post while he surveys the whole scene; however, provisions should be made for radio failure, which could be disastrous if the first in command were to be without radio contact for the duration of his walk around the fire. Therefore, when he leaves the command post he should leave someone in charge with authority to make command decisions during his absence. In this way, continuity of command can be maintained and yet the first in command can get an expanded view of the situation which will better enable him to make the right decisions.

The command post should be clearly marked for the benefit of incoming companies and others seeking directions or wishing to convey information. A strobe light on a telescoping shaft is an identification easily seen day and night, but it should be sufficiently different from apparatus warning lights to avoid confusion.

Presently accepted procedures at large fires usually call for the second in command to be in charge of the rear of the building or area with other chief officers on the flanks and perhaps inside, if inside positions can be maintained. This procedure has gone unquestioned for many years. It could be called the "vertical" command system, one in which command duties are distributed geographically, i.e., front, sides, rear—and maybe top and interior (Figure 4.2). Another system

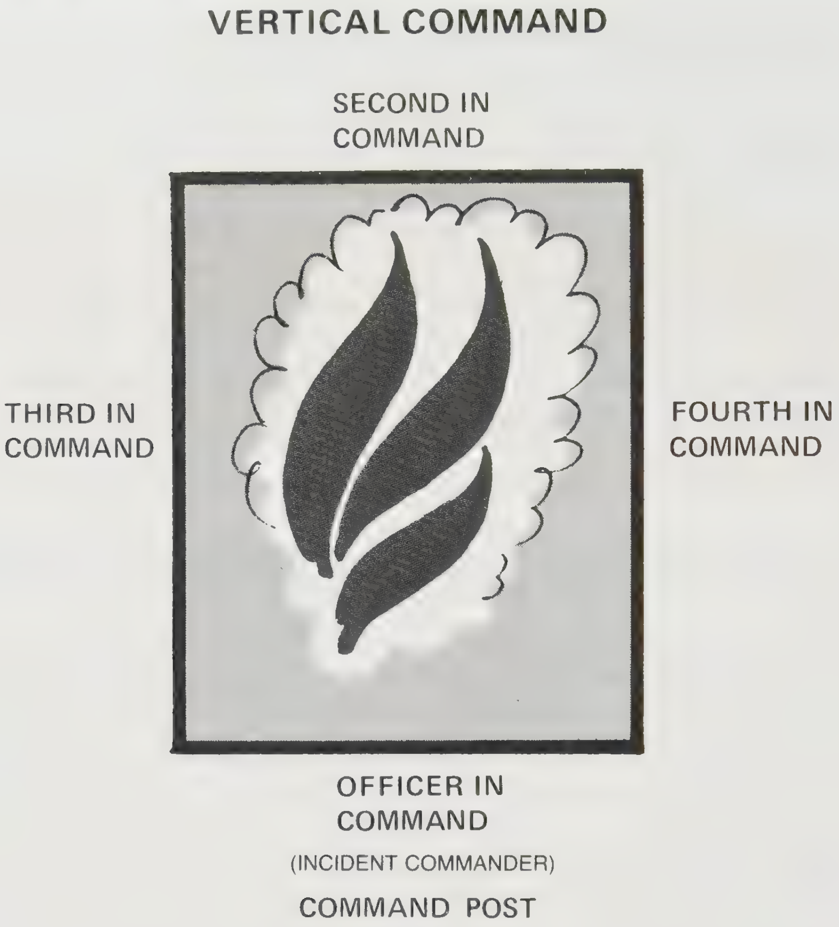
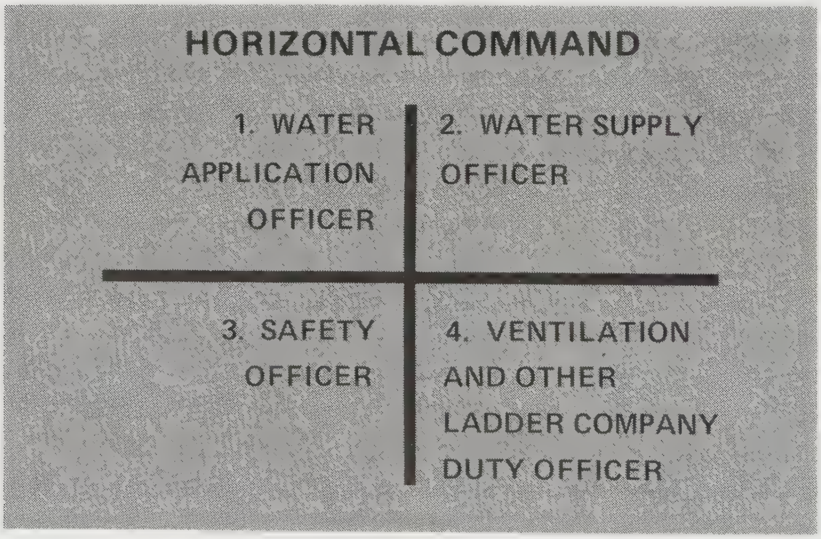

VERTICAL COMMAND
SECOND IN COMMAND
THIRD IN COMMAND
FOURTH IN COMMAND
OFFICER IN COMMAND
(INCIDENT COMMANDER)
COMMAND POST

Figure 4.2. *The vertical command system distributes command duties geographically: front, sides, rear, and maybe the top and interior of a building.*



HORIZONTAL COMMAND

1. WATER APPLICATION OFFICER	2. WATER SUPPLY OFFICER
3. SAFETY OFFICER	4. VENTILATION AND OTHER LADDER COMPANY DUTY OFFICER

Figure 4.3. *The horizontal command system assigns duties operationally rather than geographically.*

is the "horizontal" command concept in which the officers are assigned by tactical effort rather than location (Figure 4.3) In this system, the incident commander retains overall charge, but his subordinates are assigned operationally rather than geographically. One could be in charge of water application, another in charge of water supply. One would be the safety officer, another in charge of ventilation and other ladder company duties, and so on. Of course, this system also would depend on information from all sectors of the fireground. Regardless of the method used, success depends upon coordination, which, in turn, depends on communication. The need for communication is not met solely by supplying the means; it also requires an input of information.

Independence of thought may be desirable, but independence of action could be quite harmful. An officer who has an idea for action should get approval for the action if it may affect other operations. As Keith Royer has stated, "The free enterprise system of firefighting can lead to chaos, and often does."

Officers should, however, be encouraged to use initiative and take action that is consistent with the strategic and tactical objectives. The old military axiom, "Do what you were told; no less and no more," may be based on the experience of Napoleon at Waterloo. He afterward blamed his defeat on the general assigned to hold back the Prussians. When the Prussians retreated, he pursued them and kept pursuing them so far that, when the allied counterattack began, his troops were too far away to be of use against it. Therefore, it is well to seek permission for a major tactical move.

Royer has also stated that it is a mistake to apply the administrative hierarchy to fireground problems. Anyone who has observed a major fire in a large city often wonders what the large number of staff officers present are supposed to do; frequently they ask themselves the same question. We find training officers, fire prevention personnel, and other officers wandering about the fire scene trying to find something constructive to do, because department policy calls for them to be there. Some of them discreetly stay out of the way, but others feel obliged to give tactical orders, which are often resented by line officers who may be subordinate in rank but are quite conscious of line and staff distinctions. If the staff officers were given definite assignments at the fire scene which did not interfere with the orderly progress of line duties and which are clearly understood in advance by all concerned, the results might be more beneficial.

An interesting staff role at fires is that of "critic" in Japanese fire departments, whose work is to take notes of what is done wrong and present them in a report. This position would not be likely to win popularity for the officer holding it, but it might lead to improved operations. Some American fire departments have members of the training staff do something similar.

SPAN OF CONTROL

The ideal span of control at the scene of a fire will vary with the situation. It is much easier to supervise ten people who can be seen at the same time than it is to observe five people who are widely separated. Therefore, the practice of covering front, back, and both sides of a fire with chief officers usually provides sufficient supervision and coordination, even though one of them may be directing more activities and people than the others.

The "chief's aide" is a highly valuable asset on the fireground. The aide can receive and relay information and orders; make observations and report them to the chief; handle radio and telephone communications; look after the welfare of the injured and dispossessed; establish and maintain liaison with other agencies such as police, welfare, and public utility departments; give notification to other departments and individuals; and perform a variety of other duties that are not delegated to the officers present.

The role of the chief's aide can be a ticklish one. He is often in a position where he may be tempted to originate rather than just to relay orders. It is natural for officers to resent taking orders from someone lower in rank. The aide should not attempt to play chief and make up his own orders. The diplomatic aide will always relay the chief's orders in a way that makes clear that they are not his own. It doesn't take too long to say, "Chief So-and-So said that you should (whatever the order)," or, "The chief wants you to (whatever the task)." Quicker and more willing compliance will be one benefit; better morale will be another. A competent chief with a competent but likeable aide is a good combination on the fireground, which will get better results than a competent chief with a sarcastic and imperious aide.

INCIDENT COMMAND SYSTEM

Since the first edition of this book was published, the National Fire Academy started teaching an "incident command system (ICS)" which has gained wide acceptance. A succinct description of "ICS" is given in the Federal Register of March 6, 1989. It was published there to illustrate what is expected by the federal government of fire departments operating at hazardous material (haz-mat) incidents, but it is the same ICS used at fires.

Incident command system (ICS). *Paragraph 1910.120(q)(3)(ii) requires the implementation of an ICS. The ICS is an organized approach to effectively control and manage operations at an emergency incident. The individual in charge of the ICS is the senior official responding to the incident. The ICS is not much different than the "command post" approach used for many years by the fire service. During large complex fires involving several companies and many pieces of apparatus, a command post would be established. This enabled one individual to be in charge of managing the incident, rather than having several officers from different companies making separate, and sometimes conflicting, decisions. The individual in charge of the command post would delegate responsibility for performing various tasks to subordinate officers. Additionally, all communications were routed through the command post to reduce the number of radio transmissions and eliminate confusion. However, strategy, tactics, and all decisions were made by one individual.*

The ICS is a very similar system, except it is implemented for emergency response to all incidents, both large and small, that involve hazardous substances.

For a small incident, the individual in charge of the ICS may perform many tasks of the ICS. There may not be any, or little, delegation of tasks to subordinates. For example, in response to a small incident, the individual in charge of the ICS, in addition to normal command activities, may become the safety officer and may designate only one employee (with proper equipment) as a back-up to provide assistance if needed. OSHA does recommend, however, that at least two employees be designated as back-up personnel since the assistance needed may include rescue.

To illustrate the operation of the ICS, the following scenario might develop during a small incident, such as an overturned tank truck with a small leak of flammable liquid.

The first responding senior officer would implement and take command of the ICS. That person would size up the incident and determine if additional personnel and apparatus were necessary; would determine what actions to take to control the leak; and determine the proper level of personal protective equipment. If additional assistance is not needed, the individual in charge of the ICS would implement actions to stop and control the leak using the fewest number of personnel that can effectively accomplish the tasks. The individual in charge of the ICS then would designate himself as the safety

> *officer and two other employees as a back-up in case rescue may become necessary. In this scenario, decontamination procedures would not be necessary.*
>
> *A large complex incident may require many employees and difficult, time consuming efforts to control. In these situations, the individual in charge of the ICS will want to delegate different tasks to subordinates in order to maintain a span of control that will keep the number of subordinates, that are reporting, to a manageable level.*
>
> *Delegation of task at large incidents may be by location, where the incident scene is divided into sectors, and subordinate officers coordinate activities within the sector that they have been assigned.*
>
> *Delegation of tasks can also be by function. Some of the functions that the individual in charge of the ICS may want to delegate at a large incident are: medical services; evacuation; water supply; resources (equipment, apparatus); media relations; safety; and, site control (integrate activities with police for crowd and traffic control). Also for a large incident, the individual in charge of the ICS will designate several employees as back-up personnel; and a number of safety officers to monitor conditions and recommend safety precautions.*
>
> *Therefore, no matter what size or complexity an incident may be, by implementing an ICS there will be* one individual in charge *who makes the decision and gives the directions; and, all actions, and communications are coordinated through one central point of command. Such a system should reduce confusion, improve safety, organize and coordinate actions, and should facilitate effective management of the incident.*

Notice that what we called "horizontal" command in our first edition has been expanded for use at major incidents, and referred to, quite rightly, as delegation of tasks by function. Let us realize, though, that all of these functions are not necessary at a fire in a dumpster, and that in minor incidents they are not delegated, but performed by the senior officer present if needed. If, however, the situation escalates in importance, levels of command and delegation must increase until we reach the chart (Figure 14-3), and the progression should be orderly.

Our major fire departments have practiced incident command since the days when a kerosene lantern identified the command post, but without formal labeling. The term "incident commander" is perhaps more inclusive than the previous designations, such as "officer in charge," "first in command," "fireground commander," and the

Figure 4.4. *Improvements in radio technology during the fifties led to the use of specially equipped vehicles as incident command posts in major fire departments. This one, shown in Chicago in 1963, was the first to use television.*

like. The system still uses the "sectors" mentioned in our first edition but also calls them "divisions," which would have an entirely different meaning in departments that use the term in the regular organizational structure. Other terms introduced are "strike team" and "task force." "The concept of the strike team is the same as that of the task force; it allows fundamental grouping of tactical units as a team to be assigned to a task or objective in a division." The amount of personnel and apparatus of a strike team or task force can vary, and so can the objectives.

The ICS uses the New York City system for numbering exposures. The background of this system makes it more understandable. Rules required that a preliminary report be given by the first-due battalion chief shortly after arrival; it included the height in stories, type of construction, and dimensions of the fire building and each exposure. This designation was done using the points of the compass, i.e., "on the north, six-story brick old-law tenement." and so on. Then it was decided that a numbering system would avoid confusion. The sides of the fire premises are numbered in a clockwise direction as you face its front.

Exposure 1 is the front, 2 is whatever is next door on your left, 3 is at the rear, and 4 is to your right (see Figure 7-6).

Now, therefore, we get, "Exposure 1, street; Exposure 2, six-story brick multiple dwelling," and so on. These terms are used throughout the incident, although it is simpler to say "side four" than "the exposure four side" when referring to the fire building itself. Although hundreds of fire departments are successfully using these designations, the ICS manual of the NFA changed the designations to A, B, C, D in 1989.

It should be realized that preliminary reports and progress reports are made for the benefit of a superior officer at headquarters who likes to know what is going on. They should give what he needs to know—no more, no less. The basic needs of the report should be stated in department rules and should be met in the report. If he wants further information, he can ask for it. The same, of course, holds true for all radio messages.

Many adaptations may be made by small departments implementing ICS. For instance, if the chief of the department is on the scene (many respond to all fires), he doesn't have to give such reports. Other adaptations can be made easily. It is well to practice ICS and use it whenever multiple company operations offer the opportunity. This suggestion doesn't mean that all the functions of a full-blown major disaster have to be provided at lesser incidents, but they should be considered as part of an ongoing "size-up" and implemented when necessary. Most major incidents are, however, already major when the fire department arrives at the scene, and the ICS implementation should be started then to the degree that it is needed.

NOTE

1. Royer, K., and Nelson, F.W.: Using Water as an Extinguishing Agent. *Fire Engineering* 115: 1036, November 1963.

5

Firefighting Tactics

IF WE REPEAT the components of the general strategic plan as a problem in addition, we will get:

What is to be done + what is needed to do it + who is to do it = general strategic plan. If we add to that: How is it to be done, we will then have the tactical plan.

The tactics used at a fire should consist of the use of firefighters equipment, and extinguishing agents (usually water) to confine and extinguish the fire with the least possible damage to the lives and property of the occupants and with due regard for the safety of others.

TACTICAL CONSIDERATIONS

To establish an effective tactical plan, the officer in command must have sufficient knowledge of fire behavior, firefighting strategy and tactics, and how tactics and fire behavior interact.* When he arrives at the scene of the fire, he must make decisions, which are reached by weighing the firefighting resources available against the fire situation confronting him. The results of the weighing process will determine the initial action to be taken. Ample resources would indicate an immediate and aggressive offensive action. On the other hand, if analysis shows that the resources may not be sufficient for attack, they may be better used defensively.

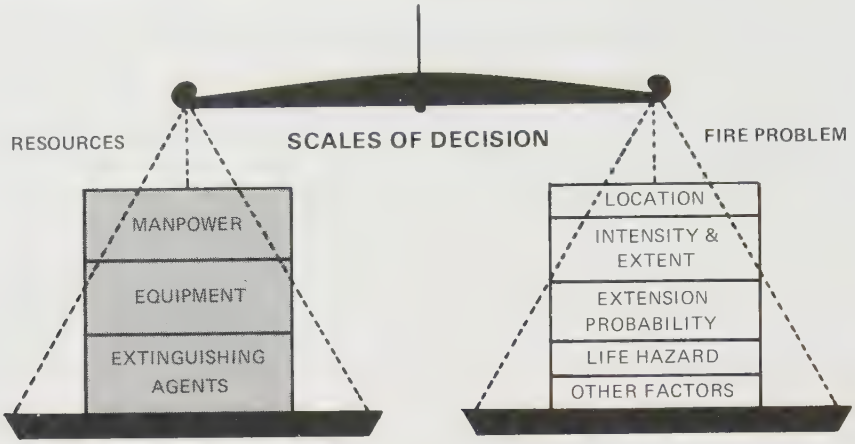

RESOURCES
SCALES OF DECISION
FIRE PROBLEM
MANPOWER
EQUIPMENT
EXTINGUISHING AGENTS
LOCATION
INTENSITY & EXTENT
EXTENSION PROBABILITY
LIFE HAZARD
OTHER FACTORS

Figure 5.1. *The factors that influence a fire officer's decision on tactics.*

Certain intangibles, such as the ability and attitudes of the officers present and the morale of the firefighters they command, are considerations of the utmost importance to the commanding officer weighing his resources. One good officer is worth a dozen poor ones and usually—but not always—a company is no better than its officers. Knowledge of officers and their companies is a valuable asset to a chief in command of the whole fireground activity or even a segment thereof.

The main observable factors (Figure 5.1) that will influence his choice of tactics are:

1. Life hazard
2. Location of the fire
3. Extension probability
4. Type of fire
5. Size of the fire

LIFE HAZARD

While life hazard is the primary consideration, it is determined by the other factors.

LOCATION OF THE FIRE

Location is most important because it determines the life hazard and the probability of extension. For instance, a fire on the roof of a 20-story hotel presents no life hazard to the occupants and very little chance of extension. On the other hand, a fire on the ground floor of the same hotel could pose a serious life hazard to all occupants on or above the ground floor; it also suggests the possibility of extending upward all the way to the top of the building.

Top-floor tenement house fires seldom extend downward, but ground-floor tenement fires often extend upward through stairways, side walls, and air shafts.

Location also indicates the probability of lateral extension.

EXTENSION PROBABILITY

The chances of fire extending are dependent on many factors. In determining the probability, the factors to be considered include the physical laws governing fire behavior. Heat rises; therefore, the chance of fire extension upward is usually the greatest, if such an opportunity exists. The heat build-up to the ignition point of exposed properties is a function of time as well as distance. Radiant heat travels equally in all directions, regardless of wind. Convected heat will be a problem downwind but not upwind.

Other factors are the combustibility of exposed materials, existing barriers to extension, and the intensity of the fire.

TYPE OF FIRE

The tactics must suit the situation. A fire in an overturned gasoline tank truck should not be fought in the same manner as a fire in an office building. Surprisingly often, such judgments are not made. There is a strong natural tendency to follow routine practices even when they are not the most suitable; if they are pursued long enough to be proven ineffective, valuable time is lost. Then when they are replaced with better tactics, the damage may be past redemption.

SIZE OF THE FIRE

The size of the fire is relegated to fifth place when compared with the four previously described factors. Size, of itself, can sometimes be misleading. A fire involving a block-square junk yard full of old automobiles, in an isolated location, is a big fire but an unimportant one. Damage will not be serious because the automobiles are going to be recycled anyway. There is no likelihood of extension, and there are no occupants with lives in danger.

Opposed to this example is a fire at the foot of the only stairway in a tenement house. Certainly this blaze is a much smaller body of fire, but one which endangers the lives of many occupants whose normal escape route is cut off, and a fire which will probably extend rapidly upward throughout the building.

What the fire has already done is not as important as what it is about to do. The key to successful firefighting is anticipation. The competent officer anticipates what might happen and takes action to prevent it from happening or, at least, to be ready for it and minimize its harmful effect.

ANALYSIS OF THE FIRE SITUATION

The command officer arriving at the scene must quickly avail himself of the information needed for intelligent decisions (Figure 5.2). There are many considerations, and although all those given here may not be applicable at all fire situations, some of them will. No claim is made that this list is original; its origin is lost in obscurity. I first saw it in 1939, and it had then been in use for many years on New York City civil service examinations. It was commonly called "size-up" or "the 14 points." What I have done here is to attempt to present these points (and a fifteenth) in the most meaningful sequence and to develop each point with a fairly detailed, but broadly applicable, explanation.

The 15 points of size-up are:

State TEST

1. Location of fire
2. Extension probability and possibility
3. Life hazard
4. Time
5. Weather
6. Construction
7. Height
8. Area
9. Occupancy
10. Access
11. Internal protection (auxiliary appliances)
12. Water supply
13. Apparatus
14. Firefighting personnel
15. Terrain

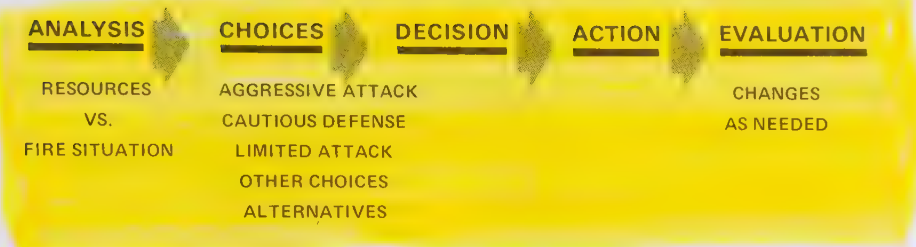


Figure 5.2. *Analysis of the fire situation leads to choices of what action to take. Constant evaluation of the action taken is needed to decide upon changes.*

1. Location of Fire

This item has already been mentioned as being one of the most important considerations for the reasons given previously; however, it should be emphasized that importance of location is not the part of town or juxtaposition to other properties so much as precisely where within a building (or vessel) the fire is. Intelligent planning requires this knowledge. How can a fire be attacked if its exact location is not known?

There are two completely opposite problems in this instance. One occurs where there is not enough fire to indicate its whereabouts (a light smoke condition, difficult to trace to its source); the other is an extremely large volume of smoke which obscures the building as well as the fire. What to do with both cases will be discussed in the next chapter.

2. Extension Probability and Possibility

If we are going to confine fire damage and save lives by cutting off the spread of the fire, it is essential that we protect all the places where it may spread. This point, too, has already been discussed to some extent. Now, let us make a distinction between probability—that which is likely to happen—and possibility—that which might happen, but is not likely. Both should be considered, but probability needs more immediate action. For example, if a gasoline tank truck overturns and the gasoline is burning in large quantity, there is a *probability* that the fire will extend to nearby buildings (as happened in Milwaukee and caused more than a million dollars in damage). But there is a *possibility* that burning gasoline may flow into the storm sewer and exit from it miles away (as happened in Minneapolis). If the sewer emptied into a river where there were ships and piers, disaster could result.

The above cases may be rare, but I use them to establish an important point. Normally, the probability of extension is more easily determined by applying knowledge of the four means of fire travel; radiation, convection, conduction, and flying brands.

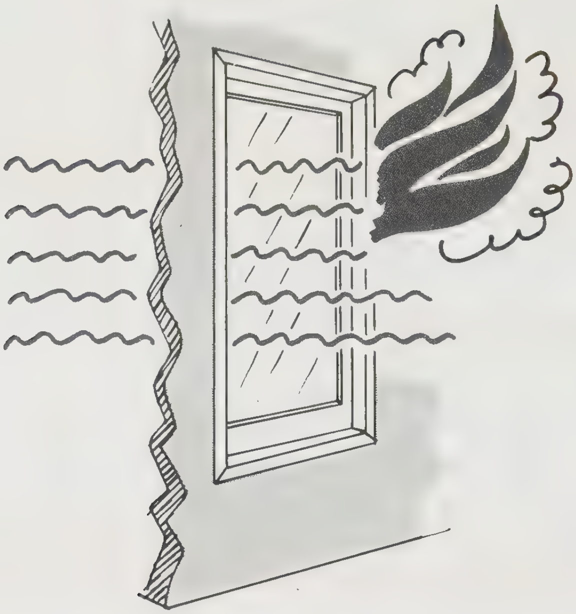


Figure 5.3. Radiant heat can pass through window glass and ignite the sash or trim inside a room.

Radiation is not frequently a problem, but at a large fire it can call for immediate action. Radiant heat travel has been described in a previous chapter. Now let us discuss some other characteristics of it and apply them to the fire situation analysis. It makes a difference whether the heat is radiating from windows (point sources) or a large body of fire such as a lumber yard (a line source). It also matters greatly just what the configuration of the exposed property presents in the way of resistance, or susceptibility to ignition from radiated heat. Combustible walls are particularly vulnerable. Masonry walls are not, but if they contain glass-covered openings (windows), their resistance is greatly decreased. Glass permits the passage of most of the heat radiation (Figure 5.3).

When a "body" such as a building, automobile, or whatever it may be is absorbing enough radiant heat to be nearing the ignition point of the exposed surface, it gives a warning in the form of a vapor emission that is easily seen; it could be said to be "steaming." Remember, when a surface is heated by radiant heat it will increase in temperature and, if heated sufficiently, will ignite. The time to ignition depends on the intensity of the radiating fire and its proximity. Protection can be withheld until the steaming effect occurs. If it can be afforded earlier, it should be, but if the defense resources are limited and might be more useful elsewhere, a "gambler's judgment" can be made. Note, however, that ignition from radiant heat usually results in a terrific change from no burning of the exposed surface to complete involvement of it in a matter of seconds. It could be said that it ignites all at once, since the entire surface reaches the ignition point at the same time.

Radiant heat travels from the flame equally in all directions; this form of heat transfer travels down as well as up. In fact, I once saw an example of it at a fire where radiation from flames, bursting out of third-floor windows, struck parked automobiles on the opposite side of the street, sufficient for them to give off the tell-tale vapors that precede ignition from radiation.

Another interesting example of radiated heat ignition occurred at one of our test fires in Wisconsin, when the heat traveled through window glass in an exposed building and ignited the inside of the wooden sash without even cracking the glass. The inside sash was burning with a small but visible flame for many minutes with the glass still intact. If there had been combustible contents near the window, they would have ignited. Yet a cursory observation from outside would show the glass unbroken and would probably lead to the erroneous assumption that the fire had not entered the building.

Windows in the same plane, opposite those from which flame is being emitted, are vulnerable to radiant heat, and this danger would normally be anticipated. Since the heat radiates from the side as well as the top, front, and bottom of the flame, however, any exposures at right angles to the path of flame are also endangered. I have seen the heat of flame from a window on the east wall of one building irradiate and enter a window on the north wall of a nearby building.

The probability of fire extension by radiation is not great at small fires but increases with the size of the fire. Most fires which extend do so by convection. Heated air and fire gases can move in many ways and directions and, after traveling surprisingly long distances, still retain sufficient heat to ignite combustible surfaces. I once saw a small fire on the stage of an abandoned theater ignite a wood two-by-four which was lying across a broken skylight 75 feet above. The fire on the stage was easily extinguished with less than 20 gallons of water, yet the convected heat rising through the broken-out skylight was sufficient to ignite a heavy piece of wood.

Convection currents from a fire travel upward until they meet an obstruction; then they travel horizontally until they find the opportunity to go upward again. This process of vertical-horizontal-vertical travel is usually the way that fire moves throughout a building. The avenues can be stairways, elevator shafts, light and air shafts, corridors, heat ducts, ventilating ducts, and air-conditioning systems.

An experiment in New York City showed that heat can travel through an air-conditioning duct and back down from a ceiling vent to ignite materials in a room remote from the fire that gave off the heat. It also showed that the poisonous products of combustion can travel in the same manner with lethal effects.

Fire travel by conduction is not frequent, but that reason—its infrequency—makes it doubly dangerous because it is not often expected and sometimes occurs extensively before discovery. Metals conduct fire readily, but other materials such as brick, concrete, and stone, do not—which does not necessarily guarantee immunity when nonmetallic materials make up the walls or ceiling in question. It is rare that fire travels by conduction through brick, stone, or concrete, but I have seen fire conduct through a 14-inch-thick brick wall. The likelihood of this kind of fire travel is remote, but it can happen; however, conduction through a steel wall or door should be expected.

Another form of fire travel, which may not be exactly conduction but could be likened to it, occurs when the beam ends of one building abut the ends of the beams of an adjacent building. This contact permits an insidious and seldom-expected means of fire travel, which can trick the unwary chief who has not prepared for it.

The situation usually occurs in older mercantile buildings situated next to similar buildings. It points out why search should be not just a one-time action but a repetitive procedure. On first examination, the building adjoining the fire building may look unendangered. Later the fire may extend from the beam ends in the fire building to those in the next building and, by the time this fact is discovered, the second building may be well involved. There have been some cases where the second fire turned out to be worse than the first.

The fourth means of fire travel is by flying brands that land on and ignite exposures, often at a considerable distance downwind. Wood-shingle roofs are culpable as both the source of the brands and the host for them in many cases. If the fire occurs at night, the brands and sparks show up bright against the dark sky. They are there in just as great number in the daytime but are not as noticeable and consequently can be overlooked.

On a windy day, a barn took fire in the town of Wales, Wisconsin. The brands from it landed on the roof of another barn downwind. That barn burned and in turn gave off embers that ignited a third barn, which set a fourth barn afire in the same manner. The fourth barn was almost two miles from the first and the shortest distance between any of the barns was one-eighth mile.

A fire in a high-rise building under construction in New York City led to brand-ignited fires in two buildings downwind, even though no wood shingles were involved. In both cases the brands entered air-conditioning intakes.

High winds may add to the problem, but are not necessary. Neither is a very large, hot fire. I once saw ignition of a wood-shingle roof one-quarter mile from a not very intense fire when the wind was only ten miles per hour. Ordinarily, built-up roofs, such as are found on flat-roofed buildings, are not susceptible to this type of ignition, and neither are tile or asphalt shingles; however, buildings with such roofs can be ignited by brands entering open windows or dropping into open shafts.

Lumber yards and similar uncovered storage spaces are particularly susceptible because they present a great area of combustible surface for the reception of the brands, as well as corners and crannies where they can nurture on easily ignited material and grow rapidly because of the quantity of fuel immediately available.

3. Life Hazard

We live in an era where great emphasis is placed upon the value of the lives of our fellow human beings, whether we know them or not. It is an accepted concept in the fire service that firefighters should be willing to risk their own lives to save that of someone they have never met. Consequently, the item of paramount importance at a fire is the life hazard.

Life hazard can be divided into three easily identified areas, the danger to: *(a)* occupants, *(b)* members of the firefighting force, and *(c)* others.

* In the first category the people most in need of help are those *(1)* close to the fire on the same level, *(2)* on the floor immediately above the fire, *(3)* on the topmost floor of the building, and *(4)* on other floors above the fire.

These locations, usually in the order given here, should receive priority when search and rescue procedures are assigned. The person shouting the loudest is not necessarily the one in the greatest danger; in fact, the most endangered may already be unconscious when the fire department arrives.

It is in the removal of many entrapped occupants that fire department personnel shortages are most notably harmful. Rescue is usually a one-to-one situation. By the time each firefighter brings one helpless occupant to safety, the chances of other endangerd occupants have diminished greatly. There are not many case histories where a firefighter repeatedly entered a burning building to rescue several persons successfully.

The next life hazard to be considered is that of the firefighters. The risk concept found in this hazardous occupation recognizes ac-

Greatest Hazards
Smoke, Structural Failure,
Explosion.

ceptance of certain dangers as almost inevitable, yet it does not re-
e personal risk unless there is no alternative. The degree
sary depends upon the situation. The risk acceptable for
ld trapped in a dwelling is not the same as that for
a fire in an abandoned building. Commanding officers
maintain a consciousness of risk value relationships and
lirections accordingly.

est hazards to the firefighting forces are smoke, struc-
nd explosion. Smoke can be hazardous in two ways: *(1)*
cicity, and *(2)* through obscuration of vision. Breathing
f value in protecting against smoke inhalation but af-
uards against the hazards of poor visibility; it may
piratory passages, but not the whole body against the
Heat is dangerous not just from the standpoint of burns
rt exposure to high temperatures, but also from heat
extended exposure to moderately high temperatures.
The latter can cause significant permanent damage to several body organs if not treated immediately and properly. Remember that breathing apparatus, like a helmet, protects part but not all of the body.

Another danger to firefighters is collapse of all or part of the fire building (Figure 5.4). They don't have to be inside the building for this to be fatal. Probably as many firemen outside as inside have been killed by a building collapse. The problem will be discussed in more detail in a later chapter.

The third category of persons exposed to the danger of a fire—and one which is frequently overlooked—is spectators. There are several examples where no occupants or firefighters were killed, but where many spectators lost their lives. A Brooklyn pier fire, which included a huge blast of explosive material, took the lives of ten spectators although no firefighters or occupants on the pier were killed. The explosion of a liquefied petroleum gas tank truck in Pennsylvania claimed the lives of one fireman and ten spectators one hour after the fire department arrived on the scene.

These examples show clearly that spectators, or others not needed to fight the fire, should be removed quickly to places of absolute safety. If there is any doubt, it should be resolved on the side of safety. If a ground-floor fire shows any possibility other than that of certain and immediate extinguishment, evacuation of all floors should be immediately started. In New York City, a fire started in a drug store; above it was a restaurant where a wedding party was in progress. The officer of the first-due ladder company went upstairs and warned the members of the wedding party of the fire below and the need for them

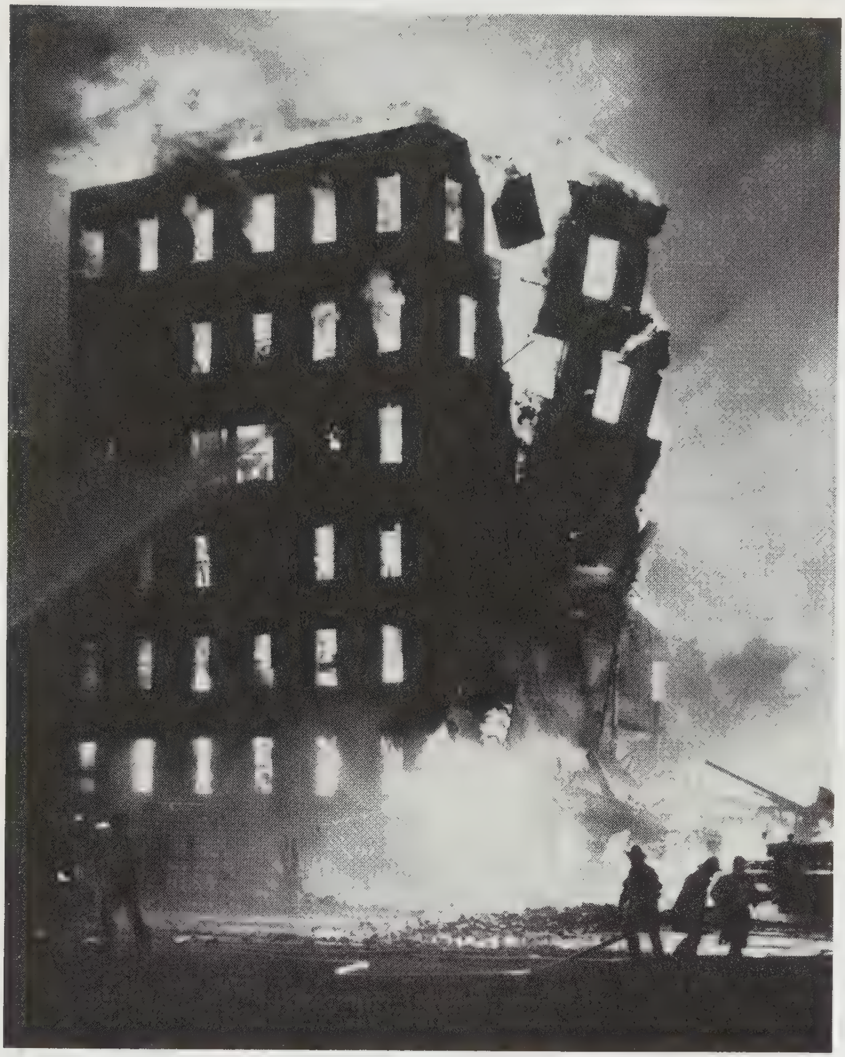


Figure 5.4. *The danger of collapse is particularly threatening at fires of long duration or high intensity.*

to evacuate. His warning was greeted derisively and completely ignored. A few minutes later, large quantities of smoke penetrated the restaurant, and the occupants panicked. Fourteen of them died.

If there is any suspicion of danger, all people on the same level or higher level than the fire should be evacuated; so should those next door if there is a question about their safety. There should be a well-planned agreement for police to keep spectators at a safe distance. In practice, this procedure is usually overdone in large cities and not even thought of elsewhere.

4. Time

The time at which a fire occurs can greatly influence the tactics used. The situation in an elementary school at 2:00 A.M. is not the same as at 2:00 P.M. The life hazard in places where people sleep, such as dwellings, apartments, and hotels, is far greater at night than by day. Not only do more people occupy such places at night, but when they are asleep they are slow to learn of their jeopardy.

Another time consideration involves the safety hazards of darkness. The possibility of accidents increases on the fireground with nightfall. Visibility decreases, and therefore firefighters walk into holes, step off roofs, are hit by hose streams and even by automobiles. Artificial illumination must be provided. Individual handlights and general floodlighting provide the solution.

The time of day also influences the time required by apparatus to reach a fire. Morning and evening traffic peaks can slow apparatus response time from three minutes to ten minutes or more.

Conditions can also vary according to the time of the week. Sundays and holidays make the situation different from weekdays in many types of occupancy. Time of year not only affects climatic conditions (to be discussed under weather), but has influence due to seasonal holidays. In the pre-Christmas period, stores are overstocked with goods and customers and, even in the evening, the streets are jammed with shopping traffic.

Another consideration brought on by time of year is the fact that in climates where artificial heat is necessary, this heat has a drying effect on buildings and contents. When a building has been continually heated for three weeks or more, its combustible components and contents dry out considerably and are much more vulnerable to the quick spread of fire than in the summer. The longer the building is heated, the drier and more dangerous it becomes.

5. Weather

Weather is certainly worthy of separate consideration from seasons because it can vary from day to day. Not every day is the same within a given season or even within the same week. The main effects of weather on firefighting are wind, temperature, and humidity.

Wind effects can be divided into velocity and direction, both of which are important. Strong winds not only accelerate a fire by giving it more oxygen, but they carry heat currents and flying brands farther. The wind direction determines which side of the fire is subjected to the greatest amount of heat. This is a factor influencing exposure protection as well as approach to the fire.

An important matter, which is often overlooked, is the effect of wind inside a building, even one that is soundly built and closed tight. Experiments in Wisconsin showed that, in masonry buildings, with all windows and doors closed, the air currents moved in the direction of the outside wind, and with velocity enough to overcome any pressure created by the fire. Fire-created pressures are miniscule and easily overcome by even light winds. Therefore, it should be recognized that fire within a building—even a closed building—will move in the direction of the wind. This knowledge can be used to advantage in heading off a fire in the downwind direction or getting close to it with the least difficulty by approaching from the opposite side. The effect may be influenced by forced-air heating or cooling units.

Atmospheric temperature affects the firefighters more than it does the fire. Cold weather presents a safety hazard in several ways. Not only are crews subjected to the physical effects of cold such as frostbite, but cold begets ice, which causes falls. It also requires heavy clothing, which reduces mobility and agility. Cold limits an individual's endurance and will necessitate relief and reinforcements in an extended fire situation. The effects of extreme cold on breathing apparatus should be noted and so should the ways in which it might otherwise obstruct operations.

Water that is flowing won't freeze, but static water will. There is no available freeze chart for water in a hose line, but if water is not flowing, it will freeze surprisingly fast at below-zero temperatures. A slight flow such as that from a barely opened nozzle may inhibit freezing at temperatures above 0°F, but when the mercury is near zero and below, a fairly good flow is needed to prevent it. At subzero temperatures, even a momentary shutdown can cause a quick freeze-up. Hydrants not drained may be frozen, and, at below-zero (F) temperatures, fog nozzles may quickly freeze.

Extreme cold (−10°F and lower) causes a quick condensation of the hot air and gases released by a fire. This phenomenon can create a cloud of white smoke and vapor that almost completely obscures vision anywhere near the fire building—even close to the ground (Figure 5.5).

Ambient heat can also be a problem, but it affects the firefighter (especially if heavily clothed) more than the fire by limiting the time one can exert oneself fully without harmful consequences. Some results of heat prostration were already noted in this chapter; other physiological effects will be discussed later.

Relative humidity is not a serious factor unless a condition of drying has prevailed for three weeks or more. It takes time for materials to lose moisture, just as it does for them to absorb it, as described

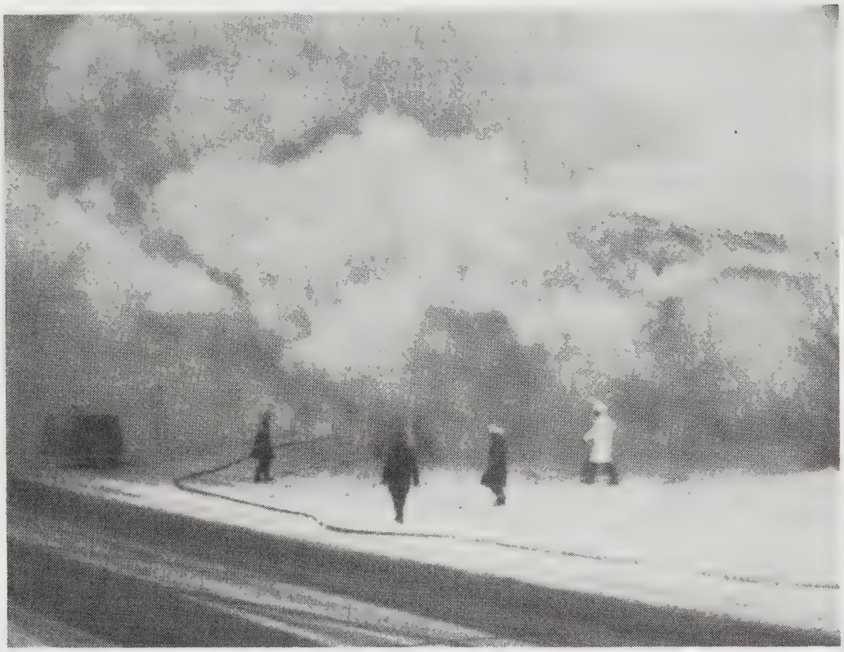


Figure 5.5. *All smoke seems white and hangs near the ground in extremely cold weather. Temperature was −12 degrees F when this photograph was taken.*

previously in discussing the heating season. In areas that have high relative humidity in summer, there can be a beneficial seasonal effect, but exceptions frequently arise.

6. Construction

The way in which fire affects a building is determined by the type of construction, the age of the building, and its condition. Some buildings resist the spread of fire, others contribute to it. Buildings with unprotected vertical arteries are particularly susceptible. Open stair, light, air, and dumbwaiter shafts are found in new buildings as well as old. Modern hazards include central air-handling systems and restaurant exhausts. The question to be asked upon arrival is, "How will this building retard or spread the fire?"

Older buildings are vulnerable for more than one reason. First, their age indicates the presence of combustible structural components such as wood joists and floors. Next, older buildings usually have unprotected stairways and other vertical arteries, and in all probability an undivided cockloft (hanging ceiling), well dried out and containing the combustible dust of many years. Such buildings were not designed with fire protection in mind; fire has much to feed upon and little to stop it. The chances of structural failure should be assessed and noted in tactical planning. They will be discussed in a chapter on structural considerations.

Mill
Balloon Frame Timber Truss
Platform Light wt Truss

7. Height

The height of a building can immediately answer several important questions. Is it all within reach of available ladders? If not, what types are needed and where can we get them? If no ladder is long enough, what is the alternative? Can outside streams penetrate upper floors effectively?

8. Area

Large-area buildings, some so huge that the most powerful hose streams cannot penetrate deep into their interiors, are becoming more common. Large areas not only require a large volume of water (as shown by the water requirement method), but demonstrate the need for getting water to the center of the building in a reasonable time and fashion. If extremely large areas are not protected with built-in equipment, they are invitations to total loss.

9. Occupancy

The purpose for which a building is used can have great influence on the outcome of a fire. It well becomes the officer in charge to find out what processes and materials it houses. This information is especially important in relation to the safety of the operating force, but

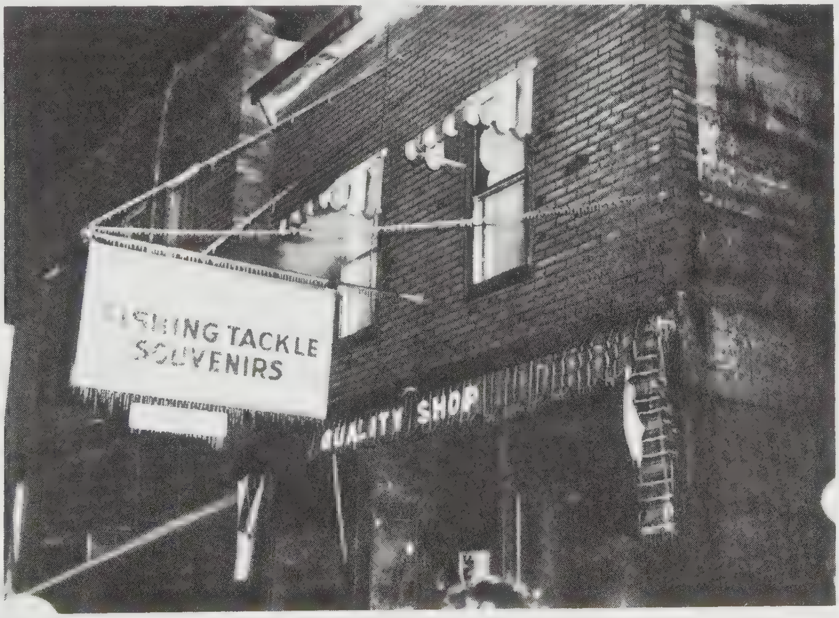


Figure 5.6. *Signs on the exterior of a fire building can provide a clue to the occupancy and materials used within the building.*

it is also helpful in determining the tactics to be used. A building might contain explosive or highly toxic substances; it could house materials which react dangerously with water, or possibly store quick-burning materials that could bring on early structural failure (Figure 5.6).

It is unfortunate for firefighters that structural alterations due to changes in occupancy usually weaken, rather than strengthen, the building. Openings are cut in girders and joists to accommodate pipes and conduits. New ducts are carried through walls and floors. Little is done to accommodate heavier floor loads. The common consequences of a change in occupancy are greater hazards to the fire department from the standpoint of safety as well as fire damage. Where the fireground analysis indicates such a change, precautions should be taken.

10. Access

The matter of access to the premises on fire is a problem which has become more complicated in recent years. The problem is now twofold: it includes access to the building itself as well as access to its interior. Shopping centers and away-from-the-street, housing developments make the approach of apparatus difficult. Aerial ladders are rendered useless when the apparatus can't be brought close enough to the building for it to be used. Sometimes ground ladders must be carried long distances. Engine companies must hand stretch hose, because apparatus can't get close enough. Parking in shopping centers and apartment complexes often obstructs hydrants as well as the fire building. Strategic considerations must provide for quick hydrant hookup alternatives when such conditions exist.

Access to the interiors of buildings is not as easily gained now as in previous years; the increase in crime has brought about an increase in the use of sophisticated locks. In past years, only the largest cities had serious forcible-entry problems due to "burglar-proof" locks. Now, many communities are faced with that problem and are finding that a size 12 boot is no longer a universal door-opener.

Windowless buildings present special access problems, which some cities have attempted to cope with by enacting ordinances requiring access panels—a compromise of dubious value to the fire department. These panels are usually hard to find, even without a fire, and when found are so small that they afford little in the way of safe access.

11. Internal Protection (Auxiliary Appliances)

Some buildings offer protection against fire as an intrinsic part of their design, which can take the form of standpipes, sprinklers, other built-in systems, and even hand extinguishers. None of these should be overlooked in tactical planning. Siamese connections on the outside of the building indicate the presence of standpipes and sprinklers. It is well to have a method which enables an incoming company to determine at a glance which siamese feeds what system. New York City developed a plan which has proven almost foolproof in over 50 years of use: the law there simply requires that standpipe connections be painted red and sprinkler connections green, if automatic, and silver if non-automatic. Thus, the officer arriving at the scene can not only tell which is which, but can decide immediately what the supply problem is. The law in New York City also requires that when a system is split, the siamese must have a sign nearby telling which area of the building it will supply.

Another New York City law which could be beneficial elsewhere is the requirement that a siamese be provided on each front of a building that fronts on more than one street. A siamese should be required near the entrance of a building. If this placement is not mandatory, the builder will probably hide the connection at the rear or some other hard-to-find part of the building.

The portable extinguisher can sometimes be of value to the largest of fire departments when a fire threatens an exposed building or is traveling rapidly through ducts or other channels where the problem is not one of size, but rather of extent. Here, firefighters can make good use of hand extinguishers until hose lines are put in place.

12. Water Supply

There are few cities which enjoy an adequate supply of water for the greatest fire potential in every part of the city. A common situation that results from the growth and change in the character of a district is the sudden discovery—sometimes after the fact—that the water supply is insufficient. The flow testing of hydrants is a sometimes overlooked facet of pre-fire planning. After such tests, each hydrant should be identified by an easily understood method to indicate the volume and pressure it will supply.

The National Fire Protection Association color code of red, yellow, and green is worthy, but this system does not truly show what the hydrant will give when used at a large fire, when several hydrants on the same or nearby mains are also being used.

Static pressure on a hydrant is not only an unreliable guide, but it sometimes is downright misleading. For example, we were conducting a pump school for a fire department in New Jersey, and the chief there had selected a quiet dead-end street as the best location. He assured us that the hydrant was fine; it had registered a static pressure of 75 psi—true, but when we flow tested the hydrant we found that it could only supply 350 gpm.

Friction loss in water mains is a factor that must be considered because it most definitely limits the amount of water a hydrant can supply. When the friction loss in the main is sufficient to reduce the residual pressure to zero, trouble will result in the form of pump cavitation and weak streams. It is disheartening to be on the nozzle of a 2½-inch hose line discharging a stream at about 10 psi, especially when some company close by has one crackling at about four times that pressure and discharging a good stream with a telling effect on the fire.

If the fire is of any size or potential, consideration should be given to selecting the best hydrants. Perhaps the first hose line can be sacrificed in the effort to get water on the fire quickly, but there is little excuse for engine companies other than the first-arriving to use hydrants that will not provide a sufficient flow if adequate hydrants are within reasonable distance.

Perhaps the best guide for the adequacy of hydrant flow is the marking of main sizes, which can be done in two ways: one is simply to paint the main size on the barrel of the hydrant in numerals large enough to be read from 50 feet by the officer of an incoming pumper, so he can tell whether or not to connect to that hydrant; another system is to use a color code to denote main size. The color can be used on the caps, the bonnet, or the barrel. Some cities use the NFPA flow code to color the bonnets, and their own main-size code to color the caps. Others use a reflective paint on the bonnets for nighttime visibility and another code for caps or barrel marking.

A means for denoting dead-end mains should also be employed. The system used in New York City is simple but effective. There the main size is shown in large numerals, and if the main is dead end, a line is placed under the numeral. Furthermore, if the hydrant has a plugged drain valve because of the possibility of salt water intrusion, the letter "P" is stenciled on the hydrant to indicate that it must be pumped dry after use to prevent freezing.

13. Apparatus

The water requirement method (refer to Chapter 4) can be quickly applied for the determination of apparatus needs. If the formula is extended to include one pumper for every 500 gpm needed and one ladder company for every two engine companies, we can soon calculate how many engines and ladder companies are needed.

14. Firefighting Personnel

NFPA 30

If the flow requirements are related to the needed personnel on the basis of * one firefighter for every 50 gpm required, the same water requirement method can be used to figure the personnel needs. It is recommended that this number be considered a minimum and used to indicate quickly whether or not personnel should be augmented.

15. Terrain

There are cities with steep hills, valleys with infrequent bridges, and railroads that can limit or seriously slow response of apparatus. There are also sections of cities which present problems through bottleneck highways, drawbridges, or other limitations of access. These factors should be considered in pre-fire planning and also in on-scene tactical decisions.

The conditions of streets generally, or in the immediate fire areas, are subjects of consideration. In winter, streets can be snow-clogged or icy. In any climate they can be congested by traffic to the point of impeding operation and access. Where street improvements are in progress, access may be limited—sometimes to a serious degree. Street excavations can prohibit the access of apparatus to the fire area; parked automobiles can interfere with ladder placement and the use of hydrants.

It should be pointed out that this book is oriented to structural firefighting and that the principles discussed up to this point have not involved wildland fires (woods, brush, or grass) to any great degree. Now, however, in the matter of terrain, it would be well to talk about such fires to a limited extent. Fires involving natural cover fuels will travel much faster uphill than on level ground, and faster on the level than downhill; these axioms can be of value when large-scale wildland fires are encountered. There have been fires, notably in the chaparral brush found in arid California, where fire traveling uphill could overtake a firefighter running as fast as possible. In any brush or grass fire, the safe procedure is to "work in the black," i.e., to approach the fire from the already burned area, which will grant ready refuge when necessary.

On some occasions there may be a justification for a firefighter losing his or her life at a structural fire. Such a calamity at an outdoor fire is hard to justify.

6

The Action Plan—Working at a Fire

AN ANALYSIS OF a fire situation is not of full value until it is used to formulate an action plan; this is the very root of its being. Such an analysis is really a study of the fire situation on which intelligent decisions can be based. An action plan must consider a number of factors, which are given here in a sequence that should be regarded as subject to rearrangement; the timing of each action will vary with the situation. Furthermore, all the items listed here will not always be essential, but they should never be overlooked.

* The 13-point action plan consists of the following:

1. Find the fire.
2. Rescue entrapped occupants.
3. Search for victims and the extent of the fire.
4. Force entry.
5. Ventilate.
6. Protect exposures.
7. Take safety precautions.
8. Establish communications and control.
9. Call help if needed.
10. Confine and extinguish the fire.
11. Perform salvage operations.
12. Notify other agencies.
13. Overhaul.

Note that only two of the 13 actions call for the use of water.

FINDING THE FIRE

If a fire is to be fought in an intelligent manner, it must be located. This task is not always easily performed. Sometimes a fire in a building is hard to find because it is so small. On such occasions, the senses of smell, sight, and touch can be of great help. Smell can often tell what is burning and therefore pinpoint the fire. Wood smoke smells different from the smoke produced by paper, which, in turn, smells unlike smoke from cloth, plastic, or rubber. Eacn burning material has a distinctive odor, which can help to isolate and find it. It is difficult to describe odors with words, but if they are experienced a few times at fires, later recognition will provide a good guide to the discovery of a fire source.

The color of smoke can also be helpful in finding fire, as the following list indicates:

Paper: light gray
Cloth: light gray
Furniture (cloth and wood combined): dark gray
General involvement of room and contents (furniture, plus paint on walls): dark gray
Wood structure: medium brown
Complete involvement of building and contents: very dark, almost black in daylight

Smoke color is different by day and by night. Much wood involvement would show a brown smoke by day, but the same smoke would appear light against the black backdrop of a night sky. Many officers have been deceived when they have arrived at a nighttime fire and seen very white smoke in the sky. It looks like steam, but if it were viewed by daylight it would be a dirty brown.

Black smoke can mean several things. From a distance it usually means any kind of structural, storage, or liquid fire. Grass and brush fires give off a smoke that looks light gray from a distance. In daylight, a structural or lumberyard fire gives off a dark smoke unless the ambient temperature is less than +10°F. Almost all smoke appears white in very cold weather.

When it is not being generated in large amounts, smoke may be an aid in finding a fire; when the amount is great, smoke can make the finding of a fire quite difficult (Figure 6.1). Large quantities of smoke can not only fill an entire building, but can sometimes fill up the street to the point where it is difficult to tell which building is on fire. I have seen cases where the smoke density at sidewalk level limited

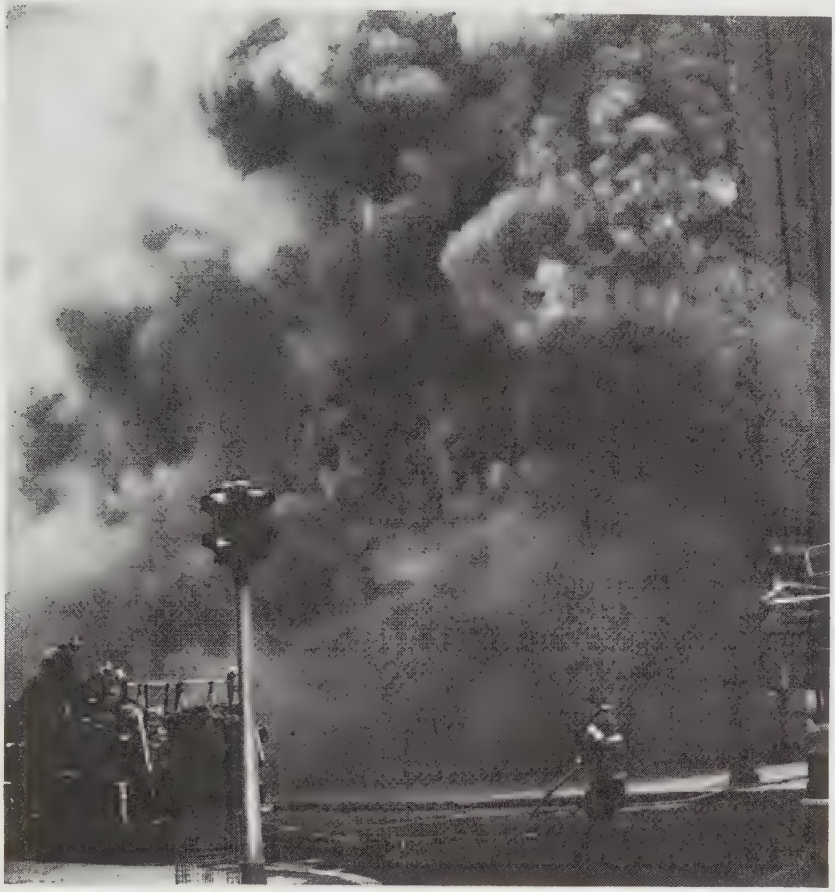


Figure 6.1. *Before ventilation: Heavy smoke obscures the building and firefighters cannot determine the location of the fire. Conditions appear serious.*

visibility to less than two feet over an entire block. On another occasion, smoke at street level interfered with traffic six blocks from the fire.

When a building is so smoke-filled that the fire cannot be found, judicious ventilation (with charged hose lines at the ready) may be the only way to find it. Ventilation not only lets the smoke escape, but, by bringing air to the fire allows it to burn brighter and become visible (Figure 6.2).

Sometimes the very size of a building makes it difficult to find the fire, but there are ways to speed discovery. For instance, a firefighter can go to the roof of a flat-roofed building, walk around the edge of it, and look down the wall for signs of smoke seeping out a window; this practice can be especially helpful when looking down interior shafts that have windows. Other shafts, too, can be examined at roof level for signs of smoke or heat. When a building is sprinklered, firefighters can listen at the risers for the sound of moving water and at locked doors

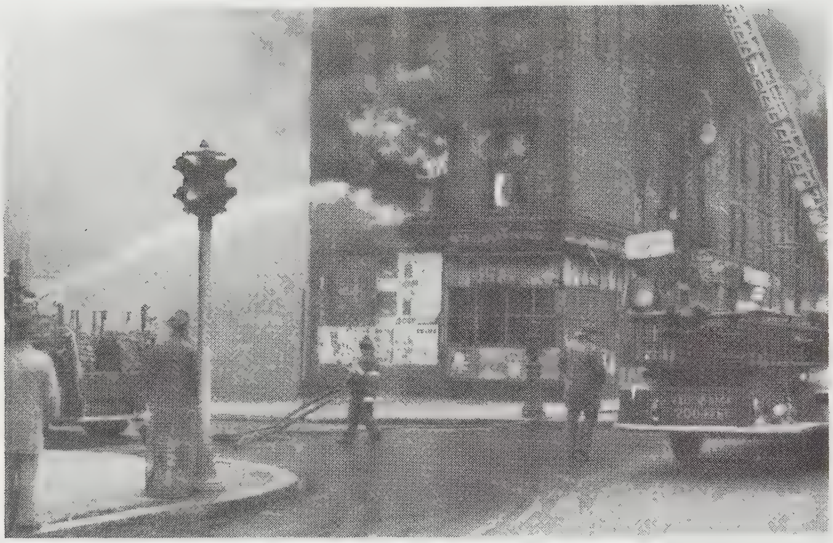


Figure 6.2. After ventilation: Smoke has lifted (two minutes after Figure 6.1.). The difference was brought about by roof ventilation. Three engines and two ladder companies easily handled the fire.

for the sound of sprinklers discharging water. In a sprinklered occupancy, fire is found occasionally by the discovery of water seeping under a door.

Locked doors can be felt by hand for signs of heat. Fire in a wall can be detected in the same manner. Often, fire in a wall or ceiling shows itself by the discoloration or blistering of the paint. Window glass often turns brown when heated and sometimes cracks slightly. Either of these symptoms can serve as a guide to the fire, as can vertical arteries such as pipe chases and utility shafts, which should be examined for signs of heat and smoke.

Smoke in any quantity is usually not found below the fire, but there are exceptional cases. Mechanical ventilation found in high-rise buildings can bring smoke to floors below the fire. Smoke may be found below the fire when sprinklers are operating, as discussed in a later chapter.

RESCUE

There are several considerations involved in rescue procedures. One is the degree of danger to the occupants; another is the method of rescue. There is also the time limit imposed on the rescuers by the fire, the number of persons needing assistance, and the personnel available. Priorities must be established when more than one person is in need of rescue, and these priorities should be determined on the basis of "who is in greatest danger." The person screaming the loudest is not necessarily the one in most need of assistance. Some people react to extreme danger with complete silence; others will shout for help at the slightest provocation. Priorities should be based on need rather than noise; however, a panicky person is more apt to jump than one who is calm although more endangered by the fire. The officer in charge will have to direct the personnel and equipment available for rescue in a way that will give such service according to the judgment of need.

When it comes to rescue, remember that buildings have four sides and that in a structural fire the danger to occupants is most acute on the fire floor, the floor immediately above the fire, and the top floor, generally in that order.

People on fire escapes seldom need help, and people on ladders are out of immediate danger. Yet we frequently see valuable personnel wasted on assisting people in those positions while there are others in real danger within the building. It should also be pointed out that when a firefighter removes a person from immediate danger to a place of temporary safety, such as a fire escape or ladder, he or she is not bound to accompany that individual all the way to the ground. He might be of far greater value if he goes back into the building and looks for people who may still be in real danger.

The quickest, the safest, and the easiest means of rescue should be used rather than the most dramatic. If endangered people can be safely brought down stairways or fire escapes—which is usually the case—there is no justification in exposing them to the time-consuming hazards of descent by ladder—particularly aerial ladders.

The use of even more exotic means of rescue such as a scaling (pompier) ladder or a life net should be discussed here even if they are rarely utilized. Life nets should be used only as a last resort. They are dangerous to the firefighters holding the net as well as to the jumper (whose fate is largely a matter of luck when the jump is from the third floor or higher). I once saw a skilled jumper get a permanent back injury in a 40-foot exhibition jump, and I have been injured myself when the rim of a net was driven into my ribs by the force of a jumper who landed too far off center. There have been cases of successful jumps from as high as 80 feet, but the injury risk at heights from 30 feet up is great and increases with the height.

Scaling ladders may be safer than the net, but they are not without risk and are difficult to use. Placing and climbing such ladders are extremely difficult, getting ordinary people to climb down one is not easy, and the task of carrying a person down such a ladder is almost impossible. When scaling ladders are used for rescue, a rope should be taken up too so that a person may be lowered to the ground rather than carried.

Officers should guard against the tendency to overdo the rescue effort to the neglect of other essential duties. It is natural for firefighters, who do not often see a person in real danger, to get excited and drop everything else for the sake of the rescue. The officer in charge should assign only the personnel absolutely necessary for a rescue, while the other crew members still perform their usual fireground tasks. Often an aggressive attack on the fire with a hose stream is the best way to save endangered people.

Emotional involvement should be avoided in rescue operations. If an officer allows himself to think about the suffering of those in agonizing predicaments, his value to them will lessen greatly, if not entirely. Understandably, it is difficult not to become unnerved when fire victims with crushed or burned bodies are lying on a sidewalk. If there are others who still need help, however, the officer must maintain a detachment from these matters and go about the business of directing operations. If he doesn't, the job won't get done, and the situation will get worse. He should emulate the professional detachment of a surgeon performing a critical operation: he has an important job to perform which could be ruined by worrying about the patient.

SEARCH

CO 200X Faster Than O_2

Most persons killed at fires have succumbed by the time that firefighters arrive. Nevertheless, there are many who die after the arrival of fire companies. They include those who are unconscious or otherwise unable to attract attention, who die—often from carbon monoxide—while the firefighters are on the scene. People in this category must be found quickly, and the way they can be found is by a systematic and thorough search. The only assurance firefighters have that all occupants are out of the building is by reaching that conclusion through their own search; the statements or opinions of an involved or excited witness are not reliable.

We have all heard assurances from civilians on the sidewalk such as, "Don't worry, fireman, everyone is out." How do they know? Often such a conclusion is reached by a civilian to salve his own conscience following his first encounter with smoke, and from which he had discreetly withdrawn after a ten-second exposure. He reasons that if there was no one for him to save, nothing was lost by his hasty retreat. So, by the time the fire department arrives, he has convinced himself that this was the case and is quick to tell the firefighters that there is no one in the building.

Conversely, there is the man who has no aspirations to be a hero. When he discovers a fire where people could be endangered, he reasons that every able-bodied person—like himself—has had a chance to escape. But there may be someone not physically able to get out; this indiviual usually narrows down to an old lady, because old ladies are not usually very agile. So by the time the firefighters arrive, he has convinced himself that an old lady is trapped within the building. And he is eager to convey this information to them. (For some inexplicable reason, the old lady is nearly always placed somewhere on the top floor.)

It is worth repeating that the only way to determine whether or not all occupants of a building are safely evacuated is by the fire department's own search, which should be done routinely at all fires, even in abandoned buildings. It stands to reason that if a fire started in an abandoned building, someone must have been there to start it. Often such persons are derelicts, but sometimes they are children. Several times I have found bodies at fires in abandoned buildings. I remember one particular fire in an abandoned tenement with another tenement in the rear that did not front on any street. An occupant of the rear tenement calmly assured me that the fire building had been abandoned for three years and certainly nobody could be in there. About three minutes later we found a man, badly burned but still alive, on the third floor.

Primary Search

Quick & Rapid

Search of a fire building should be performed systematically to avoid missing anyone. Those assigned to search should follow a pattern and use indicators to show where they have been. A chair placed upside down in a doorway will tell others that a room has been searched. Children, and sometimes adults, will hide under beds or in closets; therefore, these places should get particular attention. Another place frequently overlooked is the bathroom. I once found a woman dead in a stall shower. She had evidently panicked and thought to save herself from the heat by running into the shower and turning on the water; she was not burned but died from inhaling carbon monoxide. We could have found her much sooner if we had searched the bathroom thoroughly, but it didn't occur to us to feel behind the curtain of the shower.

I must also confide that a lack of observation on my part led to a delay in her discovery, and therein lies another valuable lesson. When I reached the fire area on the fifth floor of a walk-up rooming house, the door to the room was slightly ajar and smoke and heat were coming out. The hallway was filled with smoke, but the heat issuing from the open doorway pinpointed the fire apartment. As I entered it, I should have noticed—but didn't—that a broken chain lock was hanging on the door, which should have been positive proof that someone had been in the room when the fire started. It turned out later that a man who lived downstairs had discovered the fire, broken open the door, got a whiff of smoke, and decided the fire department could do a better job than he. A chain lock, in place or broken, is an almost positive indicator of someone's presence, although there is one type of chain lock that can be locked from the outside.

Ordinarily one would expect a padlock on the outside of a door to be a reliable indication that nobody is within. Yet there have been many cases where this was not so. In the buildings occupied by poor people, padlocks are common since they are cheap and easy to install. In this type of occupancy, you will often find children locked in while the mother goes to the store or even to work. Therefore the presence of a locked padlock is not proof of the complete absence of tenants. I have actually been present when the removal of a padlock and entry to an apartment disclosed the presence of a middle-aged man who explained that his wife always locked him in when she went out.

Secondary Search

If the fire could be considered life-threatening, a second search should be made as soon as conditions permit. The first search is called the "primary search" and is made immediately after arrival. Heat and smoke conditions can limit the effectiveness of the primary search, so a secondary search is made when conditions have abated to the point where a careful and complete search can be made to see if there are victims who were not found in the primary search.

This secondary search should include all the places where someone might have taken refuge, and places to which an individual could have fallen, jumped, or collapsed unconscious.

In addition to the locations mentioned earlier, children may be found behind large pieces of furniture, especially chairs or couches placed slightly away from the wall. Some victims fall or jump out of windows and can be found at the bottom of shafts or hidden by bushes in a yard. On occasion, victims have been found unconscious in elevators and even on top of an elevator. They have also been found covered by debris both inside and outside buildings.

Certain precautions can be taken for the safety of the searcher. That person should carry a forcible-entry tool, not only to assist in the search, but also in his or her own escape, if necessary. The searcher should not pass through a doorway without making sure the door won't close and lock behind him or her. (I made both these errors at the same time, and it almost cost me my life). A door can be kept from closing in several ways; one now popular method is to use a piece of rubber with holes that fit over the knobs on each side of the door and cover the lock. Several of these devices can be carried, and they also indicate that an area has been searched. A hose strap can also be used in that way, or any nearby portable object can be utilized to prop the door open. Some firefighters carry wedges for this purpose.

When the search is being made quite near the fire area, a charged hose line should be at hand, and searchers should try to remember where fire escapes or other exits are located in case a quick retreat becomes necessary.

Under heat and smoke conditions it is well to make the search in a crawling position, for several reasons.

1. Visibility is usually much better near the floor.
2. Heat is much less near the floor.
3. A sudden flashover or other intensification of the fire would be much more harmful to a firefighter who was standing than to one near the floor.
4. There is less danger of falling through a hole or into a shaft or other floor opening.

When an unlocked door can't be pushed open, the obstruction might be a body. People often make their way to the door and then collapse before they can open it. Therefore, if the door meets a heavy obstruction after an inch or so of travel, the door should be quickly removed from its hinges and taken down. It is almost impossible to push a door open with a person unconscious behind it.

Searching large areas such as those found in industrial occupancies while the fire is still burning can cause a firefighter to become lost in a hazardous situation. Precautions dealing with this situation are discussed in the section of this chapter dealing with safety.

When firefighters search for people, they can also search for extension of fire. Fire extension can be detected above the fire by feeling the walls for hot spots, and looking for signs of heat; the sound of fire crackling is also a valuable guide. Search for extension of the fire should be continuous. The fact that the first search discloses no fire is no guarantee that the fire will not extend later. Some fire chiefs have been embarrassed to find that a building that was well searched and found negative shortly after their arrival became honeycombed with fire a half hour later.

Ventilation is another important duty that can also be combined with search. As firefighters search, they can open windows.

ENTRY

Firefighters must gain entry to a building to perform their functions of ventilation, search, rescue, and extinguishment. If they find entrances locked, they must force their way in. Until recent years, firefighters customarily gained entry to a structure by kicking in a wood-paneled door. Not so any longer. Because of the increase in crime, wood-paneled doors have been strengthened or replaced; locks are heavier and more sophisticated. As locks become more complicated, new methods of opening them must be developed. Brute force is not enough; it is not only more damaging, but also more time-consuming. Such tools as the K-tool, pry-axe, bam-bam tool, halligan tool, Sunilla tool, and others are now available to open locked doors. The newest conception, the "through-the-lock" method afforded by the K-tool, indicates a trend away from "force-and-leverage" to that of "picking" the lock. This method is quicker and less damaging than straight force and can be used on tempered glass doors and aluminum sash doors, without inflicting costly damage.

An officer contemplating forcible entry must consider whether or not speed is necessary and weigh the need against the probable damage. In the matter of damage, it is well to remember that the door itself can probably be replaced for less than the cost of repairs of damage to its frame. Care should be taken in selecting the points of entry. The nearest and most obvious location may not be the best from the standpoint of safety as well as confinement of the fire, ease of entry, and damage.

VENTILATION

All fires give off carbon dioxide (CO_2) and carbon monoxide (CO). Carbon dioxide is odorless, colorless, and tasteless, and it does not support combustion; it is not harmful except when it dilutes air to the point where there is insufficient oxygen to support life; the likelihood of death being caused by carbon dioxide is extremely remote. At fires, carbon dioxide can usually be expelled by ventilation. Although it is normally heavier than air, it becomes lighter than air when heated by a fire and thus will rise to seek an outlet.

Carbon monoxide, the second major product of combustion, is also colorless, odorless, and tasteless. Unlike carbon dioxide, however, it is toxic and flammable.

As a toxin, carbon monoxide has the ability to supplant the oxygen contained in blood and thus can cause death. Its harmful effects can be lessened by ventilation, which will allow smoke that contains carbon monoxide to escape and be replaced by air.

Although there are other gases given off at fires, carbon monoxide is the one which is most worthy of attention. Usually other gases are present in such small percentages as to be insignificant. Methane, a flammable gas, is sometimes given off in a measurable quantity, as are other gases such as hydrocyanic acid and phosgene, which are physiologically harmful, and which are given off when wool products and plastics burn. But even when these other gases are present, carbon monoxide is usually the most potent threat to life. It is safe to say that a least 95 percent of deaths due to the inhalation of the products of combustion are from carbon monoxide.

Lack of oxygen is another leading cause, because fire can reduce the room's oxygen content below the amount needed to support life.

Smoke Explosion

The flammability of carbon monoxide is another dangerous quality. When carbon monoxide is generated, as in a smoldering fire, it may ignite suddenly with explosive force upon the introduction of fresh air.

This occurrence is commonly called a backdraft or smoke explosion. It can be avoided by making the first openings (ventilation) above the fire; in this way, the heated flammable gas can be channeled safely to the outer air. Opening doors or windows first on the fire floor or floors below can sometimes lead to a disaster under backdraft conditions.

Not only has carbon monoxide about the same vapor density as air to begin with, but it becomes much lighter when heated. Therefore it is best removed through openings above the fire. Top ventilation is also valuable in removing all the products of combustion because, when heated, they too are lighter than air, regardless of their normal vapor density.

When the gases and smoke produced by combustion escape through openings, they are immediately replaced by air. Although this exchange allows combustion to continue, it also presents advantages. The toxicity of the atmosphere is lowered and visibility is improved as the smoke is diluted with air. Smoke is a collection of tiny tar bubbles and particles of carbon so closely gathered that they often obscure vision and thus impede operations and increase the hazard. Smoke is also quite irritating to the eyes, nose, and throat; this irritating quality is actually a safeguard provided by nature. If smoke weren't so irritating, human beings would unknowingly inhale lethal amounts of odorless carbon monoxide.

The buoyancy of the combustion gases and the air heated by fire will carry the smoke upward. Cooling of the smoke can cause its particles to coalesce, thus changing its weight as well as its color. Smoke that has been cooled will become lighter in color and heavier in weight. Notice cigarette smoke—it is transparent blue when it leaves the end of the cigarette, but it becomes a much heavier light gray when expelled from the smoker's mouth, having been inhaled into the respiratory tract, where it was cooled and picked up moisture.

The same process happens when water cools smoke at a fire. The smoke becomes lighter in color and heavier in weight. The cooling causes carbon monoxide and other products of combustion to lose buoyancy and hang closer to a floor. In such cases, cross-ventilation and mechanical ventilation may be needed.

Because the products of combustion normally tend to rise, ventilation is gained at the roof level by removing covers on vertical arteries, such as stairs and shafts (Figure 6.3). When there are no normal openings above a fire, a judgment must be made as to whether or not a hole should be cut. The decision should be based on a cost-benefit determination, comparing roof damage with potential fire damage if a hole is not made. The same is true of the other damage caused by ventilation, such as the breaking of glass in windows and skylights. It can well be argued that the glass is the cheapest and most easily replaced component of the building; it would be "pennywise, pound foolish" to refrain from breaking glass to save a few dollars and consequently allow the fire to do far more damage because ventilation was withheld.

Since ventilation at fires is so important, it would be well at this point to discuss it in detail: what, why, when, where, and how.

Ventilation should not be performed in a haphazard manner. It is a function of firefighting second in importance only to the application of water—and in many cases is essential to permit the proper application of water. Every firefighter should be thoroughly acquainted with it.

What Is Ventilation? (Definition)

Ventilation, applied to firefighting, means the planned and systematic removal of smoke, gases, and heat from a structure.

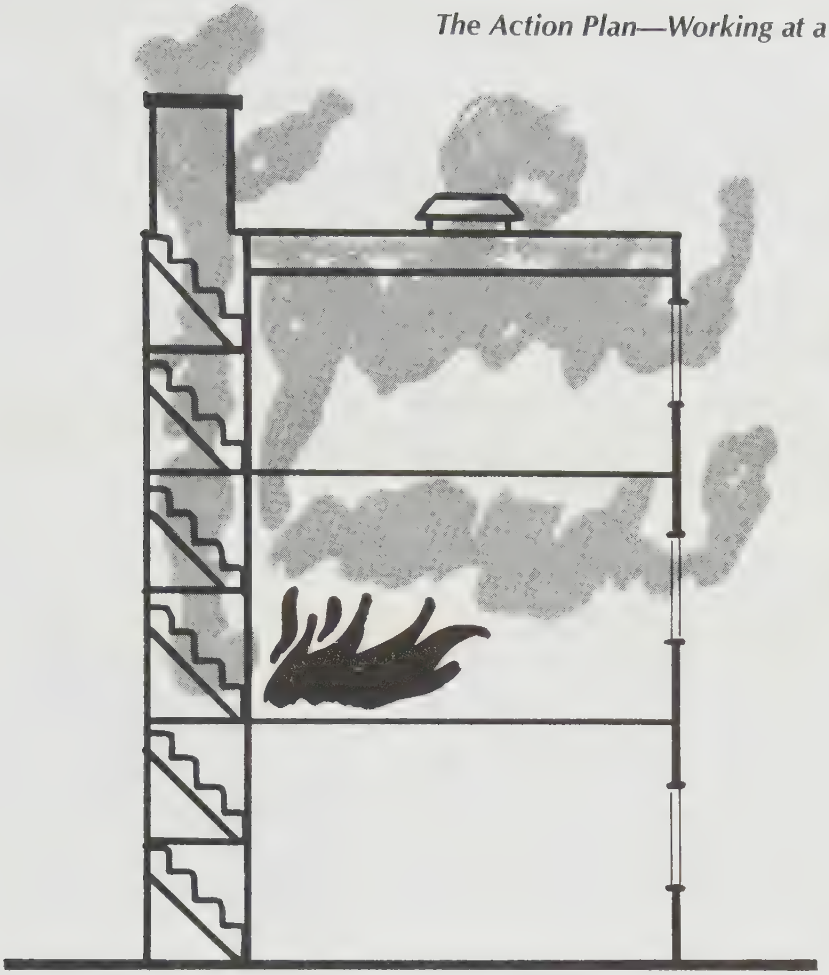


Figure 6.3. Natural ventilation can be provided on the fire floor or above it by opening windows, skylights, or the stair enclosure.

Why Is It Done? (Purpose)

Ventilation is performed for any of several reasons:

1. To save life by removing smoke and gases endangering occupants of the building who are trapped or unconscious

2. To allow firefighters to enter and remain in the building to extinguish the fire and search for helpless occupants and extension of the fire. At most fires, the purpose of ventilation is to permit the firefighters to advance close to the fire and extinguish it with a minimum of time, water, and damage.

3. To prevent backdraft or smoke explosions

4. To control the spread of fire. Heat rises until it meets an obstruction such as a ceiling or roof; it then travels horizontally, seeking an opening through which it can rise. A hole in the roof will "pull the fire" to that opening and allow it to vent upward into the

atmosphere at that location. Air currents are set up that cause the fire to move in that direction and tend to keep it from spreading elsewhere. Such an opening made directly over the fire will help to localize it, but an opening made at another spot may draw the fire there.

When Should Ventilation Be Performed?

Ventilation should be performed at fires in buildings, ships, or other enclosures where smoke is present, and also where gases or fumes have accumulated from causes other than fire.

When Should Ventilation Start? (Timing)

Ventilation should begin, ordinarily, as soon as water is up to the nozzle, not before. The procedure will allow more air to get to the fire, which will accelerate burning, and a charged hose line must therefore be ready to be moved into action as soon as ventilation begins. There is an exception to this rule: The skylight, scuttle cover, or door at the top of the stairway in a multi-storied building may be opened to prevent "mushrooming" (heat and smoking banking up on the top floor), when mushrooming would endanger human life. This step can be done without waiting for water.

Where Should We Ventilate? (Sites)

Ventilation should be performed:

1. At the roof, because heat and smoke rise, accumulate at the topmost point, then start banking down: An opening in the roof will allow the smoke and heat to escape rapidly. When there are no natural openings in the roof such as skylights, scuttle holes, and so on, and conditions are not severe enough to warrant cutting a hole, ventilation of the attic or top floor must suffice. Roof ventilation is often valuable even though the fire is in the lower part of the building, as low as the basement. A hole may be cut in the roof when there is fire in the cockloft or top floor or when fire in another part of a structure generates heavy smoke and heat that cannot be vented otherwise (Figure 6.4).
2. At windows: Windows should be opened on the floor where the fire is located and on any floor above where smoke has accumulated. Usually there is no advantage to opening windows on floors below the fire.
3. At the doorways: Doors should be opened to permit air circulation to remove smoke.

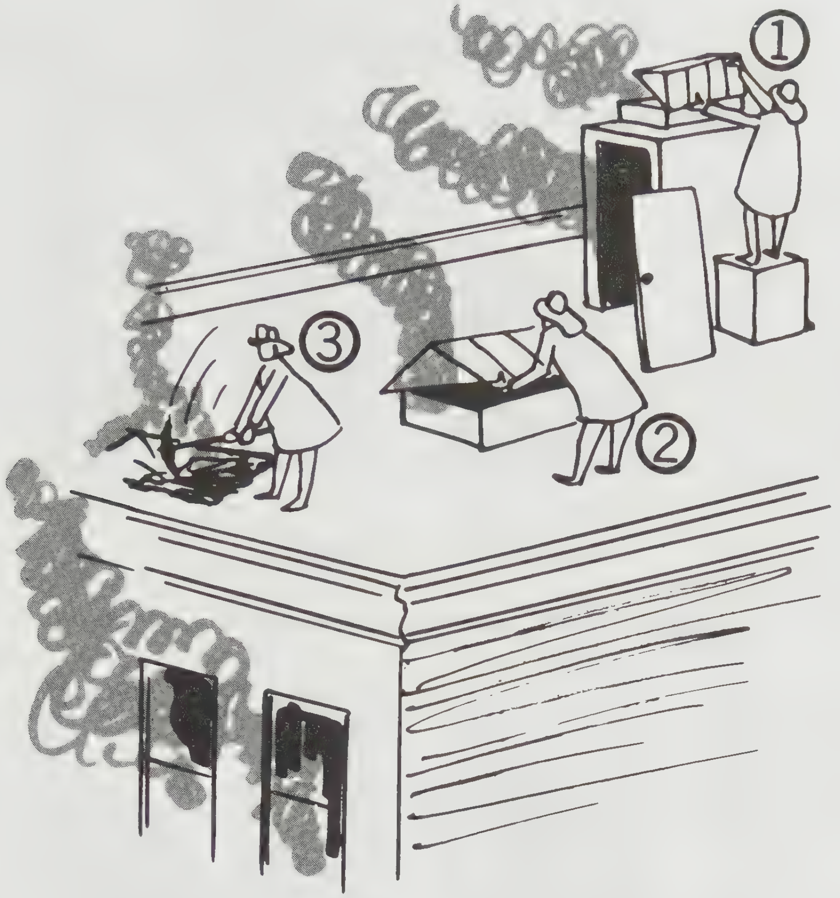


Figure 6.4. *Opening the roof: Firefighter 1 removes the door from the roof bulkhead and then the bulkhead's skylight; firefighter 2 removes the skylight over the top-floor apartment; firefighter 3 cuts a hole in the roof (when necessary) to vent a hanging ceiling.*

4. Any other covered or partly covered opening on a level with or higher than the fire should be opened.

How Should Ventilation Be Performed? (Methods)

Ventilation should be performed by:

Opening the roof: By firemen going to the roof and removing scuttle covers, skylights, and so on, and by cutting holes in the roof. One large hole is preferable to several small ones; it should be cut directly over the fire, if possible, but not at a point that would endanger an adjacent building (Figure 6.5).

Skylights may be removed by prying loose the coaming or flashing and lifting the skylight or by loosening the coaming on three sides—leaving the fourth as a hinge—and folding the skylight back on to the roof. When removal of the whole skylight is not feasible, individual glass panes may be removed without damage by prying up the metal

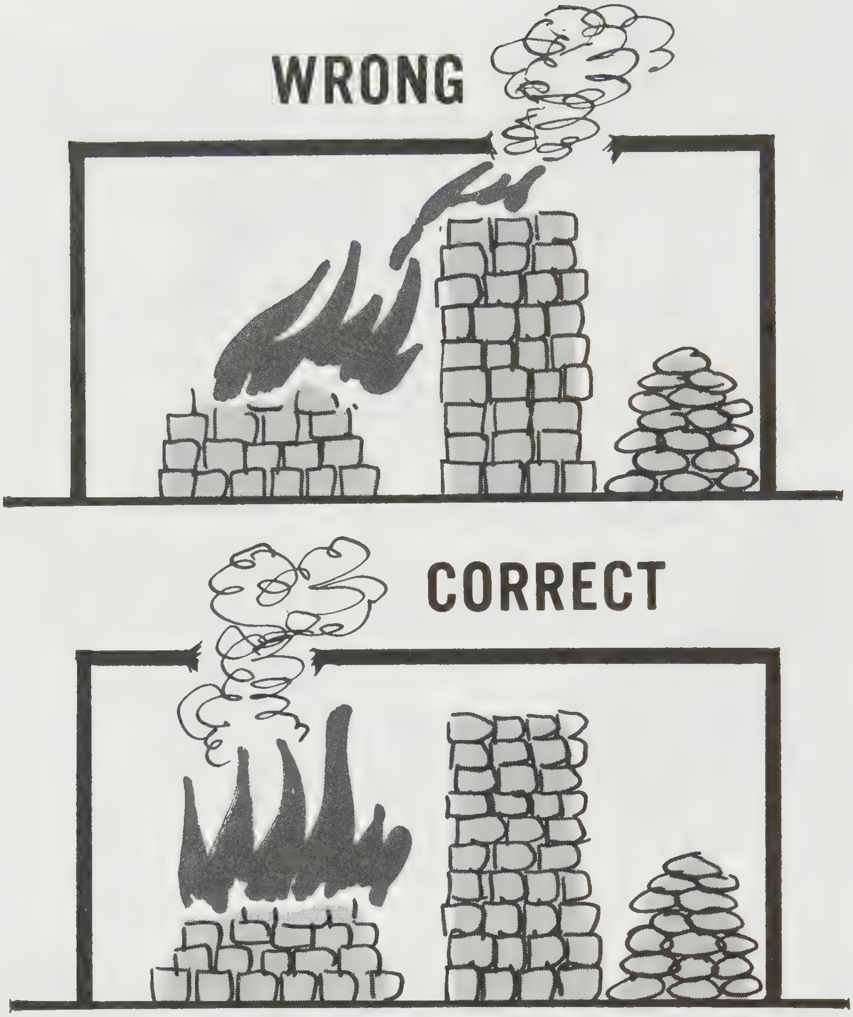


Figure 6.5. Openings for ventilation should be made directly over the fire, if possible. When they are made at a point distant from the fire, that opening can draw fire to materials that would not otherwise be involved.

divider strips and sliding the glass out. If no other means will work, the glass may be knocked out with an ax or any other tool.

When skylights are removed, there may be glass covering the opening at ceiling level, and this glass should be knocked out from above to allow ventilation of the area below it. It is well to probe any roof opening with a tool to find out if there is a ceiling or other obstruction to ventilation below that should be removed. If ventilation to the cockloft is needed, it can be provided by opening the walls enclosing the skylight or scuttle opening. If all the ventilation just described isn't sufficient, a hole can be cut in the roof. The location of the hole should be selected carefully. It should be cut directly over the fire, if possible, but not where flames and heat emerging from it would endanger an adjacent building. The larger the hole, the better the ventilation. On a flat-roofed building, large holes can be cut. A hole

Typical roof layout of "H" type building with fire in "A" wing. Trench cut in "throat" is opened only if fire threatens to spread to "B" wing. It is vital that this trench cut remains unopened until the fire reaches the forward observation holes.

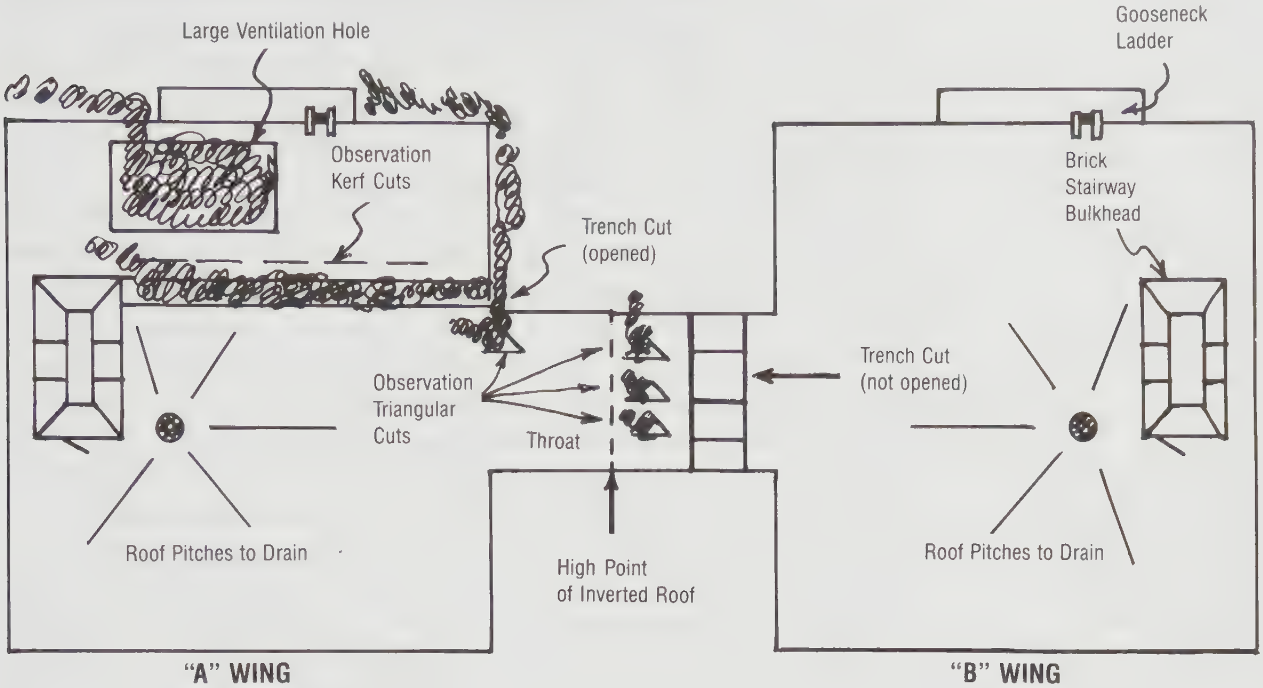

Large Ventilation Hole
Gooseneck Ladder
Observation Kerf Cuts
Brick Stairway Bulkhead
Trench Cut (opened)
Trench Cut (not opened)
Observation Triangular Cuts
Throat
Roof Pitches to Drain
High Point of Inverted Roof
Roof Pitches to Drain
"A" WING
"B" WING

Figure 6.6. *This illustration, from an article by Chief Matthew Murtagh in* W.N.Y.F., *shows several important factors in trench cutting. The term "gooseneck ladder" means the vertical ladder connecting the top balcony of the fire escape with the roof. Courtesy* W.N.Y.F. (With New York Firefighters), *second issue, 1981.*

eight feet by eight feet will give an area four times that of a hole four feet by four feet, yet it requires only twice as much cutting; a square hole gives more area per foot of cut than any other shape. For example, a cut eight feet by eight feet requires 32 linear feet of cutting to provide 64 square feet of area; a hole two feet by sixteen feet provides only half that area and requires more cutting.

Holes cut for ventilation in peaked (gabled) roofs should be made near the peak, if possible, because the highest point is where the heat and smoke will accumulate first and most heavily; however, these holes should not be made so high as to cut the ridge beam.

Remember that the fire will travel toward the hole and then vent through it. If the hole is properly placed, it will retard the spread of fire; if it is wrongly placed, it will cause fire to spread in that direction.

TRENCH CUT

The advent of the power saw led to the introduction of the "trench" cut. This type of cut is a long cut in the roof that provides a narrow hole in a location where it will separate the area where the fire is burning from the area it has not reached, but could (Figure 6.6).

Although this practice was developed in New York City to help stop the spread of fire through a cockloft, it has been tried elsewhere with success, slowing fires in areas below a roof without a cockloft. The New York Fire Department has accumulated a considerable body of knowledge on the trench cut on flat roofs, finding it especially effective in separating the wings of apartment houses—but the fact has also been learned that care and judgment are needed in its use.

The trench cut is not meant to replace a large hole directly over the fire but to supplement it. The large hole is the primary hole and should be cut first. Before the trench cut is begun, small observation holes can be made to discover how far the fire has traveled. These small holes can be just "kerfs" (small, quickly cut gashes), or small triangles. When the trench cut is made, it should be wide enough to provide an adequate vent, but not too wide to step over. It should be well away from the primary hole, at a location where it will help to stop the spread of the fire. The trench cut was once thought to provide an air inflow, but experience has shown that it functions chiefly as an outward vent; therefore, fire will move toward it, and it should not be uncovered until needed, as determined by the observation holes. The roofing may be cut in advance but left in place to be removed quickly when the fire approaches. If the cut is not made from wall to wall, fire may pass around the ends. When the trench cut is uncovered, the ceiling should be pushed down.

Additional observation cuts should be made beyond the trench cut in order to discover if fire has passed it. If it has, then another trench may be cut farther on; the first trench cut will still aid in slowing the fire.

Safety precautions include deciding on an escape route before cutting, not stepping on the roofing which has been cut but not yet removed, and staying off the roof over the fire side of the cut once it has been uncovered.

Trenching has also been tried with success on a sloping roof. An experiment was tried by the Fire Service Institute, University of Illinois, on a long, one-story, horse barn, 30 feet wide. The roof, which had a considerable slope on each side of the peak, was cut from side to side, with the exception of the ridge board, with a trench three feet wide. The report states that the fire traveled horizontally under the roof at a speed that ignited the rafters at a rate of one every four seconds until it reached the trench, where it slowed greatly and was stopped by handline streams from below. During one of the test fires, flames moved past the trench but were soon pushed back by hose streams. After these tests, it was felt that a wider trench would have been more effective.

OPENING WINDOWS

On the fire floor and floors above it, the windows should be opened. If conditions permit, this task should be done by firefighters working from the inside. Blinds and shades should be raised or removed and drapes and curtains pushed back or removed to permit the smoke to escape; screens should be removed and storm windows removed or broken out. Some say that double-hung windows should be opened two-thirds of the way from the top and one-third from the bottom, but this method is of little consequence. The main point is to get the window open at the top to let the smoke escape. Fresh air will find its way in to replace it.

Good cross-ventilation can be accomplished by opening the windows on the leeward (away from the wind) side of the building at the top, and those on the windward side from the bottom, allowing the wind to flow in the open bottoms, pushing the smoke out through the open tops.

Casement and factory-type pivoting windows have to be opened according to their design. Many windows are difficult or impossible to open when time is important (at practically all fires). If smoke conditions warrant, they should be broken.

A quick way to break windows above the ground floor is by raising a ladder and letting the top of it fall against the window. The ladder can be moved from window to window, and do the job much faster and more safely than a firefighter working from a ladder. There is a danger from falling glass whenever glass is broken, however, and firefighters should avoid being hit by it.

Above the plate-glass door and show windows in some stores there are light glass transoms, which are easily broken and often afford ventilation, while the show window is allowed to remain intact. In extreme cases, the whole show window may be removed. In either situation, if there is a partition between the store and the show window, it must be removed to provide adequate ventilation.

BASEMENT FIRES

Basement or cellar fires present special ventilation problems. Of course, windows and doors, when present, should be opened. Sometimes windows are recessed in openings that are covered with an iron grating at street level; this grating may be removed by breaking the concrete at the corners, or the bars may be spread and a pike pole inserted to break the window glass. When deadlights (small sections of heavy glass) are present in the sidewalk over a basement, they may be knocked out with the back of an ax or a maul. The removal of chute covers may also assist ventilation. In some stores, the removal of panels under the front of the show window gives direct access to the basement, affording good ventilation. Where no other means is effective, a hole may be cut in the floor above the basement; this hole must be guarded by a charged hose line. Hot-air grilles in floors can be utilized by removing the grille and pushing down the hot-air duct; this action will have the same effect as cutting a hole in the floor and is faster and less damaging.

VENTILATING AN ENTIRE BUILDING

When an entire building is to be ventilated, such work should begin at the top of the structure and proceed downward, floor by floor. If the lower part of the building is opened first, fire may break through the window openings there and make ventilation of upper floors impossible or even endanger firefighters who may be ventilating or performing other duties above the fire.

MECHANICAL VENTILATION

In addition to the methods of ventilation by natural means, movement of smoke, gases, and air can be forced by mechanical devices. Fans of varying size are employed by many fire departments. These usually range in capacity from 5,000 to 15,000 cubic feet per minute. Common fog nozzles can also induce a great amount of air to follow the fog stream and ordinarily can move from 10,000 to 30,000 cubic feet per minute, depending upon size, type, fog pattern, and location of nozzle.

Since the use of fans has become popular, there is a noticeable tendency on the part of some fire departments to neglect natural ventilation. In fact, many poorly trained fire departments depend almost entirely on mechanical ventilation and overlook the advantage of opening windows and other methods previously described. Smoke ejectors can be valuable when properly employed, but they are best when used as an adjunct to natural ventilation or in cases where natural ventilation is ineffective. In many instances, the time and personnel employed to put smoke ejectors to work would be better used in effecting natural ventilation.

If natural ventilation has been tried and the results are not satisfactory, the smoke ejector can be put to work. Remember that, if not properly used, these fans can do more harm than good. An exhaust fan will draw the smoke and fire toward the place where the fan is located; therefore, the location of the fan must be carefully selected. This problem was exemplified at a fire in the attic of a one-story dwelling. The firemen were able to enter the ground floor with ease; only a slight amount of smoke was present there. They placed a blower fan in the front doorway and an exhaust fan in the rear doorway. In a moment, a large volume of smoke was drawn from the attic into the first floor, and the firemen were driven out of the building. A few seconds later, fire came through the ceiling.

Fog nozzles have been used for ventilation for more than 100 years, yet today we find many fire departments using them only for extinguishing the fire. To remove smoke with a fog nozzle, the nozzle is held inside a window or doorway and aimed toward the outer air. Experiments show that to obtain maximum air movement, the fog pattern should almost cover the entire opening, but leave some room around the edges. Also, better results are obtained when the nozzle is a few feet back from the opening than when it is close. The nearer the nozzle is to the exit opening, the more outside air will be entrained. The same precautions mentioned for the use of fans apply also to the use of fog nozzles for ventilation.

The effects of mechanical ventilation by fog nozzles were first studied by Fitzgerald in New York in 1957[1]. He reported air movement as great as 144,000 cubic feet per minute. Air movement depends upon the size of the openings as well as the fog pattern and nozzle pressure. Larger openings will permit greater air movement than smaller ones; therefore, a door might provide a better opening than a window. In his excellent article, Fitzgerald points out that when a fog nozzle stream was directed toward the open doorway of a building, the pressure reading on the floor above was .02 inches of water below atmospheric, but when the nozzle was reversed and directed into the building, the pressure on the floor above went up to .02 inches of water above atmospheric.

His measurements showed that a fog nozzle on a 2½-inch hose line operating at a nozzle pressure of 100 psi will cause air movement with a velocity of 1,000 feet per minute and a discharge of about 30,000 cubic feet per minute through an opening measuring 30 square feet. Smaller openings, of course, would restrict the flow. Wide-angle fog should be avoided even when the opening is very large. Fitzgerald explains that, as the path of the water moves nearer to a right angle to the line of air flow, it loses much of the energy that moves the air forward.

Other experiments showed that fog nozzles on 1½-inch hose will generate air velocities of 1,200 feet per minute at 100 psi and 60 gpm, with slight increases as gpm and nozzle pressure are increased. The amount of air moved will also depend on the area of the air intake as well as that of the discharge opening.

Comparisons with currently available smoke ejectors show that a fog nozzle operating at 100 psi, and discharging 60 gpm, can move 20 percent more air than a 10,000-cfm fan. Of course, there is the problem of water damage, which may be difficult to avoid in some circumstances when water is used to ventilate.

With either fans or fog nozzles, the size of the openings used and their locations are limiting factors. A device creating an air velocity of 1,000 feet per minute would move 20,000 cubic feet of air per minute through an opening of 20 square feet, provided the intake openings to the room had a gross area equal to, or larger than, the exits. The amount of air moved would be less in proportion to any reduction in entrance and exit areas.

Mechanical ventilation is accomplished by artificially creating a low-pressure area at the point of exit so that smoke suspended in the enclosure to be ventilated will move to that area. When the entrance ports are not sufficiently large to provide a flow equal to that being discharged, air from other parts of the building will flow into the low-pressure area, sometimes coming from stories above, sometimes from stories below and sometimes from between the walls. I remember a case where we discovered fire between the walls of a building when a fog stream directed out a second-floor window brought fresh, hot smoke to the nozzle. It was interesting to note that each time the nozzle was closed, the flow of fresh smoke stopped. When the nozzle was reopened, however, air was drawn in between the walls on the first floor and accelerated the burning there, thus creating the heat and smoke that came to the nozzle at the second-floor window.

Mechanical ventilation can be of considerable help at a fire, but its principles should be well understood and carefully applied.

POSITIVE-PRESSURE VENTILATION

When portable fans operated by gasoline engines were introduced, it was soon discovered that their usefulness as smoke ejectors was limited by the smoke. If it was too rich, the smoke would stall the engine and stop the fan. Then it was learned that, when the fan was placed outside the building and directed to "push instead of pull," clean outside air would displace the contaminated air inside the fire building. This practice became known as "positive-pressure ventilation" and was widely used in Los Angeles and some other parts of the Far West for a few years before the idea spread to other parts of the country.

In some areas, it was greeted skeptically as another example of grasping for the mechanical "quick fix," but many who have used it say that it is a valuable tactic. There is a notable lack of hard data from scientific study to confirm or deny the various arguments for and against it, yet no doubt exists that the fan will push a large volume of air. The question is what benefit or harm will that bring; the answer depends on how and where it is used. Like many other concepts, its benefit is in proportion to the knowledge of the user.

A researcher who has conducted considerable testing of it is Homer Robertson of the Fort Worth, Texas, fire department. His findings are well expressed in some of his writings.

Robertson suggests using this method to clear smoke out of a residential structure quickly after the fire has been extinguished. For most effective use, he lists these requirements.

1. The cone of air from the fan must cover the intake opening to form a seal around the opening.
2. The discharge opening should be at the highest and farthest point, if possible.
3. The size of the discharge opening should be three-fourths to one and one-half times the area of the intake.
4. The path of air movement should be controlled by opening and closing doors, windows, scuttle holes, and so on.

He suggests that a two-story structure be ventilated by first clearing the first story and then closing the first-story discharge so the air will move upward. He has also found that the system can control air flow in high-rise structures and limit smoke spread in strip shopping centers after the fire has been extinguished.

This technique raises questions about the advisability of using forced ventilation when the fire is still burning. Some advocate it and others are appalled at the very thought of pushing all that oxygen into a fire. Furthermore, the velocity of the air movement may force the fire into uninvolved areas. Robertson offers several warnings, including caution in ascertaining the exact location of the fire and placing hose lines in proper positions before starting the fan. He claims that benefits during fire attack may include better visibility, lower temperature, and less steam build-up.

Ventilating Ships

Some fire departments may be called upon to fight fires aboard seagoing cargo ships. Ventilation aboard these ships calls for "trimming" ventilators; that is, turning the ventilating funnels away from the wind. The removal of hatch covers also provides ventilation, and remember that there may be additional hatch covers at the "tweendeck" levels, including lazarets.

Engine rooms are often equipped with skylights similar to those on the roofs of buildings, which may be opened in the same manner.

Precautions in Ventilation

Firefighters should remember that a hose stream directed into a window, doorway, skylight, hole, or other opening has the same effect of nullifying ventilation as if the opening had had a cover placed over it. Even worse, it may drive heat and smoke throughout the building.

Openings should not be made where they may jeopardize nearby structures by extending the fire, unless adequate protection in the form of hose streams is at hand.

When holes for ventilation are made in a floor, they should be cut near a window, if possible, so that the smoke can exit through the window. Another reason is that if the firefighters with the protecting hose line are driven out of the building, they may be able to direct their stream through a window to cover the hole. It is not desirable to cut holes in the firefighters' path of travel because they may step into them. If it is necessary to cut such a hole, it should be blocked with a chair or other available object. Whenever a hole is cut in a roof or floor, or a skylight or scuttle cover is removed, the opening should be probed with a tool to find out if there is any obstruction, such as a ceiling, below the hole. When such an obstruction is found, it should be opened or pushed down.

Before breaking glass, make sure no one below will be struck by falling glass. Warning should be given in ample time. Large pieces of glass can sail a considerable distance.

All the Effects of Ventilation

Constantly consider that ventilation will cause the fire to grow rapidly and will increase the temperature in the fire compartment (Figure 6.7). Even ventilation above the fire will accelerate the burning rate by allowing fresh air to replace the oxygen-deficient atmosphere that was slowing combustion. We conducted an experiment which clearly illustrates this point in the old burn building at the Florida State Fire College (see Figure 6.7). The fuel source for the fire was an array of wood pallets totaling 10,000 pounds. Newspapers scattered among the pallets were ignited, and the fire grew in almost straight-line progression with all windows, doors, and skylights open, reaching a ceiling temperature of 1,470°F with only a very slight reduction in the percentage of oxygen. Then, as the roof openings were covered and the windows closed, the oxygen content dropped, and so did the temperature. When the roof vents and windows were reopened, the temperature rose rapidly (Figure 6.7). With all windows and roof vents open, the oxygen content and temperature continued to rise until water attack was made at the 20-minute mark.

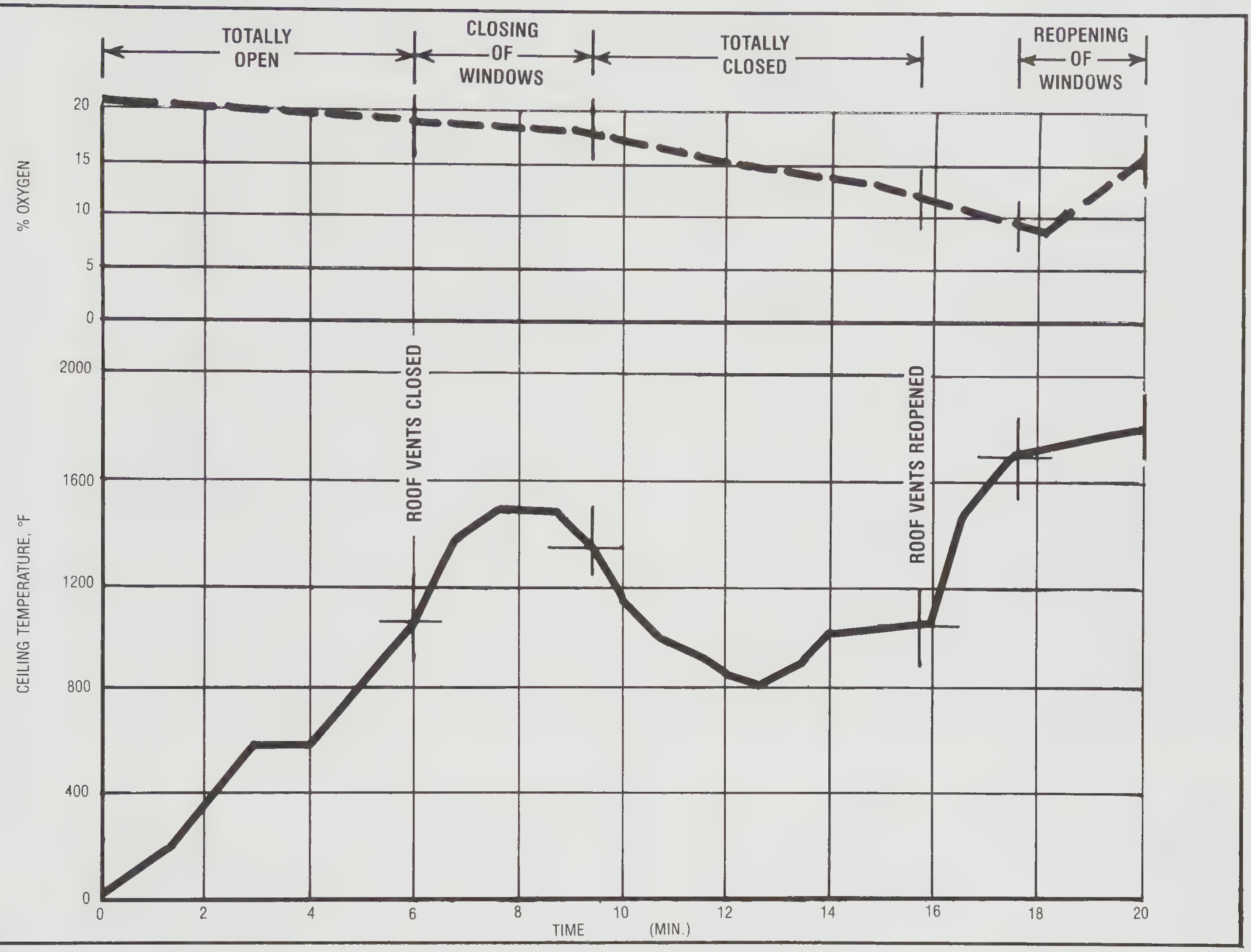


Figure 6.7. *This graph shows the progress of a fire for the first 20 minutes after ignition. The fuel source consisted of 10,000 pounds of wood pallets arranged in a stack 40 feet long, eight feet wide, and five feet high on the second floor of the fire-resistive test building, which measures 40 feet by 40 feet, with a ceiling ten feet high. Ignition was begun by lighting four piles of paper and cardboard placed among the pallets. No flammable liquids were used. As the graph shows, the temperature rose rapidly to 1,470 degrees F and then dropped as the windows and roof vents were closed, rising again after the vents were opened until the ceiling temperature reached 1,780 degrees. The top portion of the graph shows the percentage of oxygen measured at a point three feet above the floor, and it is clear how that was affected by the opening and closing of the windows. Note that, at the 18-minute mark, the oxygen content has dropped to 9 percent, but the fire was rising in temperature.*

Other experiments have measured rate of burning through weight loss of the fuel source and show that top ventilation will increase the rate even without the help of windows. In some cases, the increase was dramatic, with the "doubling time" cut in half—meaning that the fire was doubling its energy output (growing) twice as fast after being ventilated.[2]

The experiments not only make clear the dangers of premature or indiscriminate ventilation but have also caused some question as to whether ventilation is always as desirable as was previously thought.[3]

PROTECTION OF EXPOSURES

Protection against extension of a fire can take many forms. The application of water is the one most commonly used, but the others should not be forgotten. Many times fire extends from one part of a building to another through an open fire door, which should have been discovered and closed. I have seen fire extend from one building to another through open wire glass windows, which would have stopped the fire if they had been closed.

The probability of extension can be divided into two main categories. The first is extension within the structure itself; the second is extension to other properties. While the latter is usually less likely, it is often given paramount consideration, because its consequences can be severe.

Extension to other buildings (usually termed "exposures") can be guarded against by placing hose lines in these structures to keep fire from entering. (If an exposed building has a standpipe system, it can be quite helpful in this procedure.) The walls of exposed structures should be kept wet—and thus below ignition temperatures—by hose streams applied to the exterior. (See Chapter 2 for a discussion of the mechanics involved.) Usually a combination of interior and exterior protection is the most effective, if it can be done simultaneously. An application of foam to windows and walls can provide temporary protection, but the coating must be renewed as it is dissipated by heat.

Sometimes the closing of windows, doors, and fire shutters will be sufficient to prevent extension. At other times, the removal of combustible materials that are stored near windows will be necessary. Remember that radiant heat travels through glass and can ignite combustible material in its path.

There have been occasions when quite primitive measures, such as the use of hand extinguishers and buckets of water, were successful in keeping fire out of an exposed building. I discovered a remarkable case when I did a study of the Detroit riots for the Department of

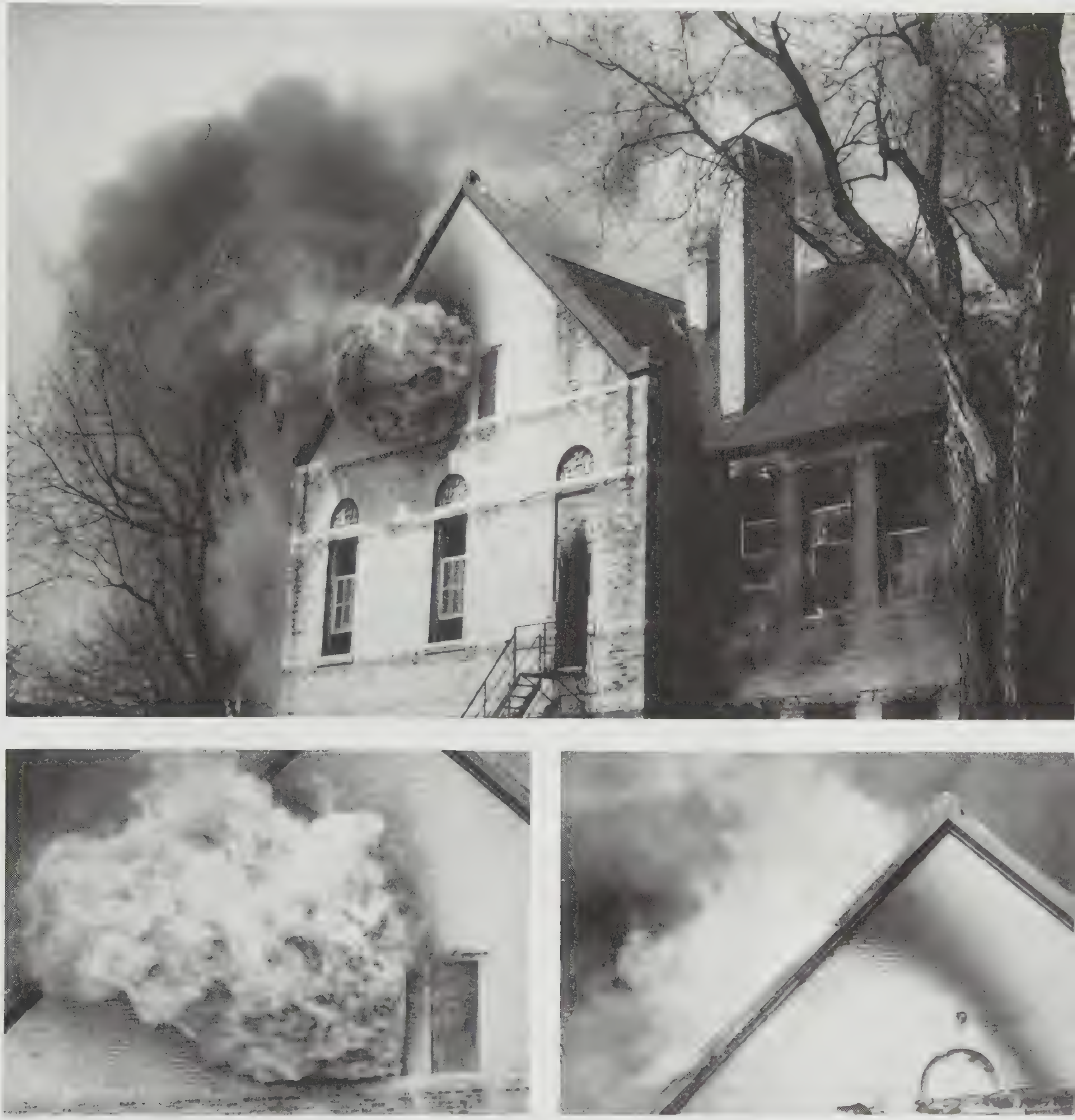


Figure 6.8. A., B., and C. *This fire in the attic of a school vents forcefully through a window until a hole burns through the roof. The fire then vents through the roof opening, and the window becomes an air intake. This change will lessen the hazard to nearby exposures and will allow the entry of hand lines.*

Defense. There, one man with a garden hose saved a two-and-one-half-story dwelling while the surrounding buildings burned to the ground, including an identical building ten feet away. When the ruins had cooled, his house stood like a monument in the midst of the rubble of 16 buildings that had been completely destroyed. Remarkably, it suffered no damage at all.

Establishment of Priorities

In establishing priorities for the protection of exposures, there are other considerations which may have more importance than proximity to the fire. Inasmuch as life hazard is always of paramount importance, it should be emphasized when exposure priorities are being established. Take the situation in which a factory is badly exposed because of its proximity to a fire. Add to this a hospital near, but not as near as the factory, to the fire. It may be better to risk the

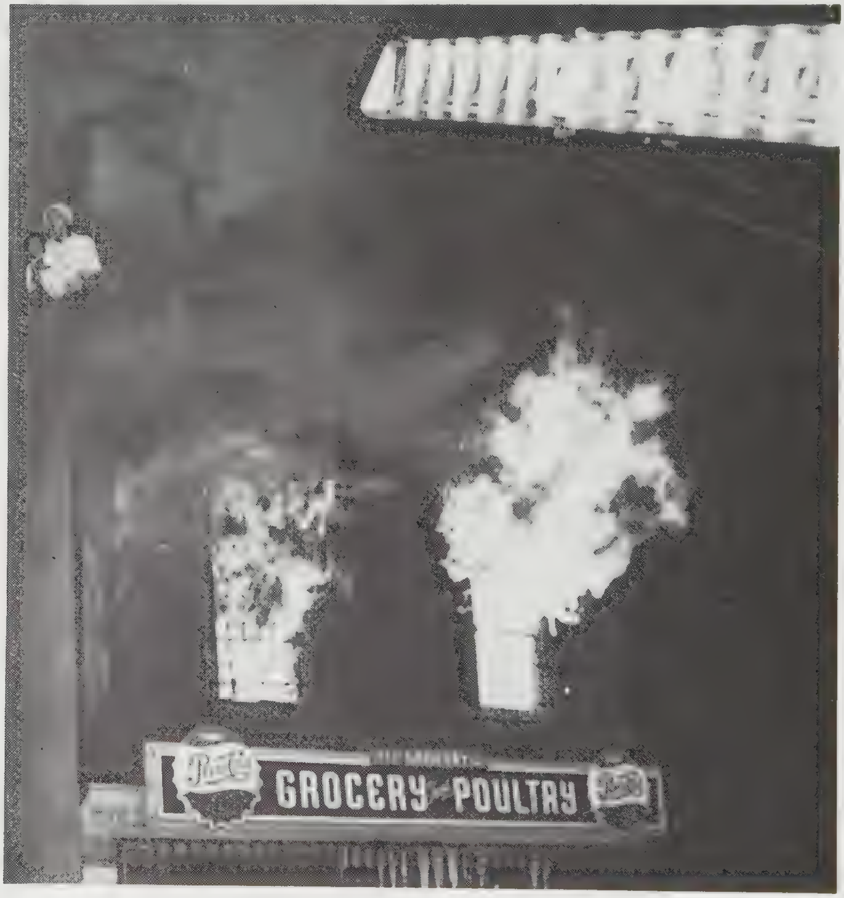


Figure 6.9. Rescue of a woman and child, at the upper left. The ladder had to be so positioned that the rescued and the rescuers were not exposed on the way down to the flame coming out the windows.

property loss of the factory than chance the severe loss of life that could happen if the fire involved the hospital.

Another consideration other than that of life hazard is the relative importance of the exposures to the economic life of the community. Suppose the nearest and most exposed building is an ordinary dwelling, but the next exposure is a factory employing over 300 people. If the dwelling is saved but the factory is lost, which outcome has the greatest effect?

Still another consideration is that of the hazard if the exposure becomes involved. It could be a building containing explosives or flammable-liquid storage, either of which could greatly complicate the problem if involved with fire. These factors must be considered when priorities are established.

The protection of the exposure, then, must be determined by a plan that will fit the situation, through the consideration of life hazard, economic importance, and fire extension probability, rather than just proximity to the original fire.

Vertical Extension of Fire

The extension of fire within a building is far more likely than extension to other structures. Remember that fire is most likely to travel vertically and that vertical arteries offer the most likely path. Such arteries include stairways, elevator shafts, dumbwaiter shafts, air shafts, light shafts, air-conditioning ducts, kitchen ducts, utility channels, pipe chases, and others. Even where building codes require that these arteries be protected, there is always the chance that they won't be. Workmanship defects can provide means of fire travel. The existence of building codes provides no guarantee of compliance with them, and the complete elimination of violations is almost impossible. I well remember visiting a building in Wisconsin that was erected in strict compliance with a code that required a three-hour fire resistance of the floor between the basement and first floor; however, the first floor was occupied by a drug store with a soda fountain. The soda fountain had carbon dioxide gas and other supplies in the basement that needed piping. The owner solved this difficulty by cutting several ten-inch-diameter holes through the floor, thus nullifying its fire resistance.

Other chances of fire spread will be discussed under structural considerations, but the effects of sparks and brands should also be evaluated and guarded against in the action plan. Patrols should be stationed downwind when there are flying brands that could spread fire to other premises. Equipment for the patrols can range from brooms and wet mops to hose lines.

SAFETY

Safety at fires involves three groups of people: the occupants, the firefighting force, and others. The safety of the firefighters will be discussed in a chapter dealing with that subject in detail. The safety of others has already been discussed in previous chapters. It should, however, be noted at this point that actions to ensure the safety of operating forces, occupants, and others should be considered in the action plan.

COMMUNICATION

The ability to control is limited by the ability to communicate. Fireground communications are threefold: communications up to the command level, down from the command level, and from the command level to headquarters.

The fireground commander has three methods of communications available: two-way radio (portable or fixed), telephone, and direct oral communication.

The flexibility of portable radio is of great advantage, as has been previously discussed. Its use in the action plan is two-way, figuratively, as well as literally. It can transmit orders in one direction and information in the other, but the latter use is sometimes neglected. Radio should not completely exclude direct oral communication. There are still times when a face-to-face discussion is needed on the fireground.

There is great need for radio discipline. Procedures should be spelled out, clearly understood, and closely followed, or confusion can result. One big weakness in present-day radio communication is "open key" failure, which occurs when a transceiver is accidentally left in the transmit position, thus rendering that frequency useless for all transmissions. Unfortunately, a broadcast notifying all units to check for this deficiency cannot be heard at the offending unit; therefore, the best procedure is for each unit to check the next nearest unit when notified of this condition. Coordination, command, and control in relation to the action plan are discussed in another chapter.

CALL FOR ADDITIONAL HELP

Somewhere in the action plan, provision has to be made for calling additional help, whether it be personnel, regular equipment, or special equipment. The personnel and regular equipment needs have already been discussed, with one exception, which is the advisability of having one unit standing by for immediate use. It is axiomatic in military strategy that at least one unit be held in reserve. In a large battle, this unit would be a division; in a skirmish, it would be a company or maybe a platoon. The main thing to be remembered is that there should be at least one unit standing by ready to be used instantly if the occasion demands it. Sometimes a sudden shift by the fire would call for the quick use of the standby unit; another time its need would be to save a company trapped by the fire. In either case, it is more desirable to have a unit ready on standby than to reposition a unit already committed. Even if the first commitment is not extremely vital, the time needed for change could be fatal. Therefore it should be noted that while minimum personnel and equipment requirements can be calculated by the ideal-rate-of-flow formula, there is still a need for reserve forces. These should be added to the minimum established by the formula.

The time to call for additional help occurs as soon as the need can be determined. Valuable time can be lost while the forces and equipment on hand are tried and found wanting. It is better to call help too early than too late. If not needed, the help can return to quarters without harm. There may be an excuse for calling help when it isn't needed, but there is hardly an excuse for not calling it when it is needed. The question can be asked, "What are the assigned second-alarm companies doing now that would be more important than being at the fire, even if they just stand by there?"

Old-time chiefs took pride in holding a fire with a first-alarm assignment. It was a matter of pride to show that they could control the situation by tactical skills, rather than by large amounts of men and equipment. They were not wrong, although some of them overdid it; conversely, it is the "easy out" to keep calling for more personnel and equipment. Too much of both can complicate the situation. The best procedure is to decide what is needed, call for it early, and employ it properly.

The type of fire influences the kind of equipment and the amount of personnel needed. A grueling fire which is hard on the crews may require additional personnel for relief of firefighters but no additional apparatus. On the other hand, a fire which calls for special extinguishing agents or techniques might require more equipment but no additional personnel. An assessment of needs should be followed by steps to meet those needs, such as the calling of personnel, special apparatus, special extinguishing agents, special crews, and expert specialized advice.

If the situation changes, the needs may change; however, a thorough analysis should enable the officer in charge to anticipate needs and be prepared to meet the changes that can be reasonably expected.

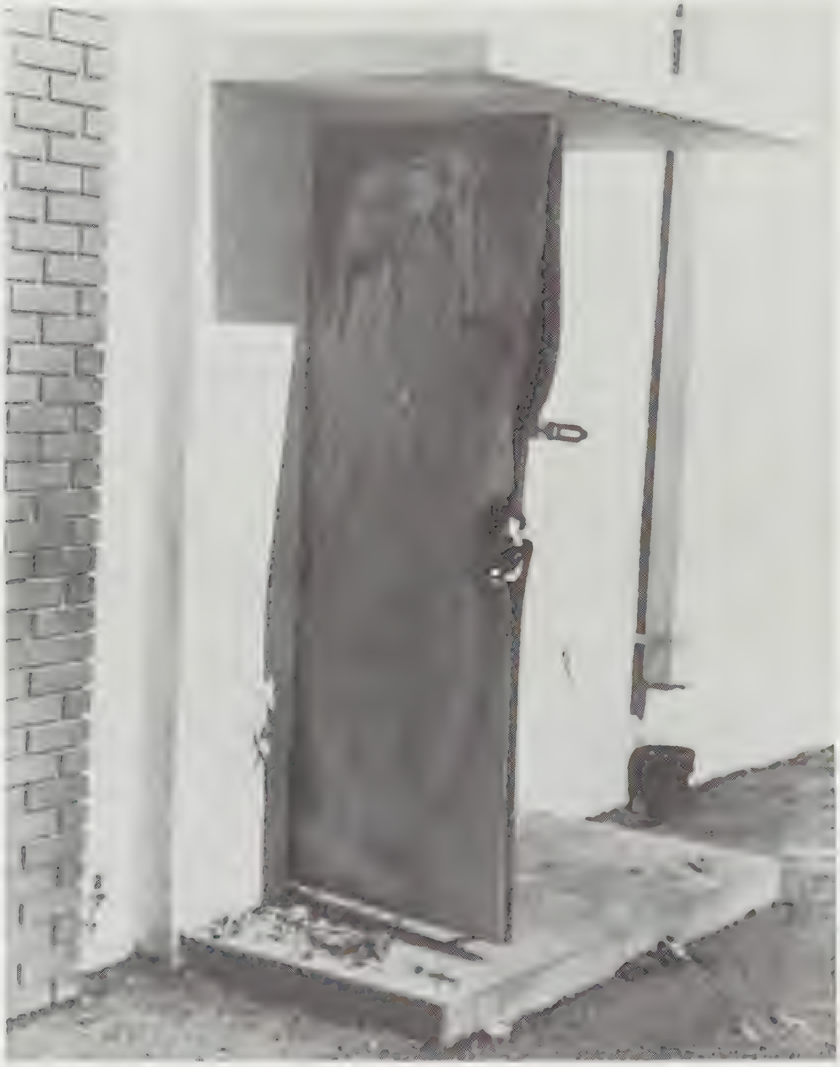


Figure 6.10. *Firefighters, armed with simple tools, took too much time to open this door; the consequence was a heavy fire loss in the building.*

EXTINGUISHMENT

Of course, the basic matter of extinguishing the fire is of prime importance in the action plan, but I have withheld it until now to show that, while it is important, there are other considerations which may have to be decided upon first. To avoid redundancy, the reader is referred to the specific chapters on extinguishing methods. But in developing the action plan, the following must be considered:

1. Placement of hose streams
2. Water requirements
    a. To confine
    b. To extinguish
3. Selection of sizes and types of nozzles and hose
4. Need for agents other than water

SALVAGE

Salvage should begin with the arrival of the fire department. Although personnel shortages do not always permit prompt and adequate salvage, the subject should be included in the action plan. Some of the procedures are simply and quickly done without need for special equipment. For instance, if it is necessary to pull down a bedroom ceiling, the materials on top of dressers and chests can be quickly scooped into top drawers which are then closed. A rug makes a fairly good makeshift salvage cover. Ventilation can lessen smoke damage.

In a commercial occupancy, the problem is more acute. Not only is there more valuable stock exposed, but the size of it requires more personnel. In some cases, second- and third-due companies can be used for salvage work. One saving feature is that new warehouses and factories in many cities are only one story in height, therefore lessening the chance of water damage and the need for salvage covers. The judicious use of water provides a salvage function without a need for additional personnel. Fear of water damage, however, should not become such an obsession that it results in greater fire damage. A progressive fire department will have some salvage equipment and plans for using it for protection against water and smoke damage, and also for covering openings made in roofs and windows so that the building interior and contents will be protected from the elements.

COOPERATION OF OTHER AGENCIES

Nearly always the presence of police at the fire scene is of help. They can control traffic and spectators so that the former does not interfere with operations and the latter are not endangered. Sometimes police are needed to protect the firefighters from inhabitants of the area. At any rate, the action plan should consider police cooperation and the need for more police in some situations.

Another provision is that of medical aid for those injured at the fire, whether civilians or members of the fire department. Welfare authorities may have to be contacted for the assistance of families distressed by the fire, and other agencies may be needed to handle other problems. The health department should be notified when foodstuffs are involved. The telephone, electric, or gas companies may have to be called when such utilities are involved. And in some rarer cases, it may be necessary to notify federal agencies or a branch of the military. Railroad authorities may have to be called on some occasions, and sometimes the advice or equipment of private industry can be of help.

Investigation services such as those provided by the state fire marshal or the fire department's own bureau of investigation are often needed. The sooner these people are notified, the better they like it. The same is true of sheriffs', state police, or local police investigative services. All these notifications should be included in the action plan so that they won't be overlooked or delayed.

OVERHAULING

Simply defined, overhauling is a thorough examination used to make certain that a fire is completely extinguished. In the usual application, it is the entire process of making sure that no sparks or embers remain to rekindle a fire, which might again spread through the premises or materials involved. Overhauling should not be considered part of salvage work or determination of fire cause; it is an important function of firefighting, and one that should be dealt with separately. It should also be clearly understood that overhauling is not merely "wetting down" burned materials; it is performed more with tools than with water.

Overhauling is necessary because fire tends to remain unnoticed in concealed spaces of a building, behind walls, above ceilings, and under floors, in cracks between boards, and so on. Also, combustible contents such as upholstered furniture, mattresses, rugs, clothing, rubbish, and stocks such as papers and cloth may contain hidden fire.

As soon as visible fire is extinguished, overhauling operations should begin. Usually there is no need to start in haste; a little time spent planning for a systematic overhauling job will save time and effort, prevent injuries, avoid needless duplication, and get better results.

Operations should be planned so that an examination is made of every place where fire could possibly remain or have extended (Figure 6.11). This search can range from the opening of a mattress to the shifting of all the contents of a warehouse, from punching a small hole next to a light fixture to pulling down the entire ceiling of a large building.

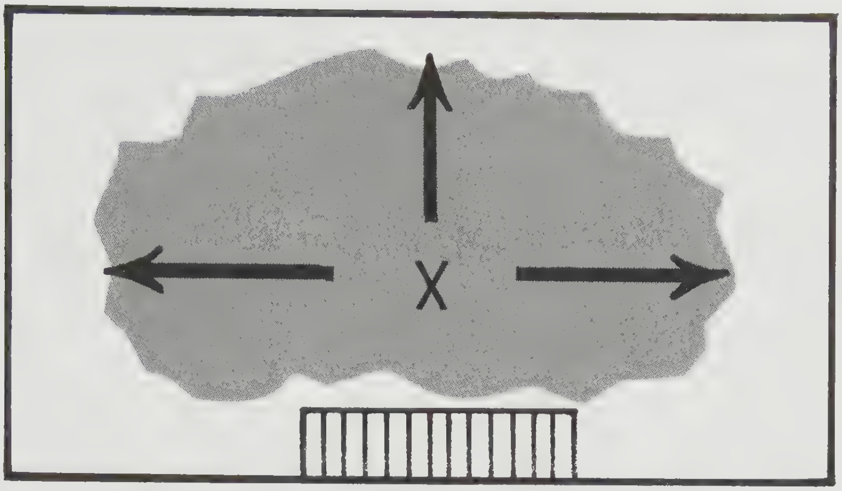


Figure 6.11. *Overhaul should be systematic, with the starting point preferably made at the center of the burned area, from which firefighters can work in two or three directions—four, if possible.*

The plan for overhauling operations should be based on location, intensity, and extent of the fire, type of construction involved, and type, amount, and distribution of contents. The first step is to use hearing, sight, touch, and smell to discover hidden fire. Fire in a ceiling or wall may be indicated by a crackling sound, or by blisters or discoloration. Fresh smoke issuing from cracks in floors or around baseboards is another sign of remaining fire. Sometimes the smell of smoke will indicate what material is burning and give a clue to its location. Touch may be used by feeling for hot spots along walls and floors.

Whenever these signs of hidden fire appear, it is logical to make openings to uncover and extinguish the fire. Remember, however, that a wall that has had its surface exposed to the heat of the fire may feel hot and yet not have fire behind it. An old firefighting tip says that if you can hold your bare hand on a lath and plaster wall long enough to say, "It's hot, Chief," then there is no fire at that point.

Of course, you cannot depend entirely on these noticeable signs. There are frequent occasions when judgment is the only guide. If there has been intense heat in a room, you may reasonably assume that it might have spread through the ceiling. Therefore a small portion of the ceiling may be opened for examination. The point chosen for this examination should be the place where the fire appeared to be most intense or where there is an opening such as a light fixture or pipe channel. If, after the ceiling has been opened, evidence of charring is disclosed, more of the ceiling should be removed until all of the charred area has been exposed. If cobwebs are observed, it means that there has been little or no heat there, and no further examination is needed in that area.

Window and door frames are places that require particular attention. Hidden fire is probably found here more often than in any other part of a building. It is a simple matter to remove the casing or trim, preferably the trim, because it can be taken off neatly without damage and left for the owner to replace.

When an examination is made to discover fire travel in a wall of a room above the fire, the least damaging way to open that wall is to remove the baseboard and puncture the plaster in the area previously covered by the baseboard. When the baseboard is later replaced, it will cover the hole.

Sometimes it is necessary to remove floorboards to get at or discover the fire. The most efficient way of doing this, from the standpoint of ease of operation and cost of replacement, is to cut the boards alongside the beams they rest upon. The location of these beams may be determined by sounding; that is, tapping the floor with the top of the ax head. The hollow area between beams will emit a deeper sound.

Whenever possible, structural overhauling should be done from the interior of the building. It is not only easier and more effective to open walls from the inside but less damaging in terms of repair cost.

Exterior overhauling operations may include opening of the roof, opening roof and window cornices, and removing burned shingles or siding. The same procedure described for floorboards is used to remove roof boards after the roofing material has been taken off to expose the boards. Tin or built-up roof coverings are cut and peeled back. Shingles can be pried loose with a claw or similar tool or the pike of an ax. A quick and easy way to remove shingles is with a shovel.

A good way to cut up roof coverings around a skylight or other opening is to cut diagonally outward from each corner and then peel back the roofing material between the cuts (Figure 6.12).

Overhauling Contents

The overhualing of furniture mostly concerns mattresses and upholstered furniture. Fire can burrow deep into stuffing material and smoulder for days, which requires that the material be pulled apart and thoroughly examined. A safe procedure is to remove a mattress to a place where its reignition would do no harm. The fact that a mattress or sofa is well soaked with water is no guarantee that all fire in it has been extinguished. An experiment was once conducted in New York of lowering a burning bale of cotton into the East River and leaving it submerged for a week. When it was removed, the bale was broken open and fire was still smouldering within it. The use of water con-

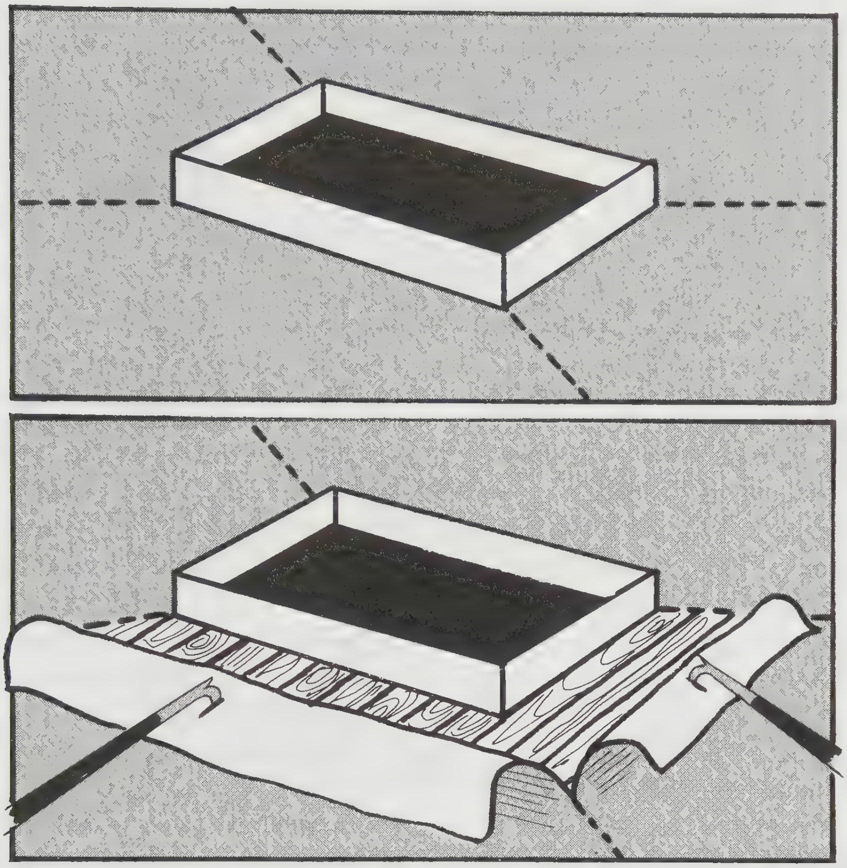


Figure 6.12. Trimming around a roof opening: Dotted lines indicate cuts that are made diagonally from each corner, with an ax or a cutting tool. The roofing is then pulled back to uncover the boards.

taining a penetrant ("wet water") is helpful but does not entirely remove the necessity for pulling apart burned materials.

Burned clothing should be separated from unburned and thoroughly examined. A common way to overhaul clothing or bedclothes that are still burning is to remove them to the bathroom and submerge them in a bathtub.

Two common overhauling procedures that are actually seldom necessary are "scraping char" and "washing down." The scraping of char from wood surfaces for fear that the charred area will reignite spontaneously is hardly worthwhile because the likelihood is so remote.

The procedure known as washing down is frequently overdone. It seems incongruous that firefighters will endure extreme punishment in getting close to a fire to extinguish it with a minimum of water, then an hour or more later use three times as much water to wash down an area that has been overhauled. If the overhauling has been competently done, and the examination has been thorough, there is little justification for the traditional washing down. About the only time it may be justified is when it is believed that fire may remain in some crevices that are difficult to uncover or examine; a small amount of water may be directed into such spaces. But the wetting of exposed surfaces is a useless and sometimes damaging procedure, usually caused by overcaution.

Non-Structural Overhauling

Some specific overhauling problems arise frequently. One involves the automobile. The first step is to disconnect the battery, unless it has been determined that that had nothing to do with the fire. Burned seat cushions should be removed from the vehicle and completely overhauled. If there is a possibility that fire extended into the contents of the trunk, that should be opened for examination. Burned wires should be scraped or closely examined. Floor mats should be inspected on their under sides, and the under side of the vehicle itself should be examined to see if any grease or insulation is burning.

Fires in lumber yards or other places where stocks of wood are involved will often require the moving of burned lumber—a tedious but necessary procedure.

The same is true of coal piles, hay storage, and piles of rubbish or similar materials. Burned hay also presents a safety problem. Firefighters should stand on planks or ladders to keep from falling into pockets where the hay has burned to ash.

Fires involving large amounts of baled goods frequently call for the removal of the bales to the outside of the building. Forklift trucks or hand trucks are often on the premises and can be utilized if still serviceable. If the goods to be moved are on upper floors, a window opening can be continued down to floor level (by removing the window apron) to facilitate removal of burned material. If such removal is required on more than one floor, the openings should not be made on windows directly above or below each other. The removal of window aprons in direct line may weaken the wall (Figure 6.13).

Safety Precautions in Overhauling

It has been said that more firefighters are injured during overhauling operations than in any other phase of firefighting. Great consideration therefore must be given to safety.

A safety item of prime consideration is structural stability of the building. If the fire has possibly been severe enough to weaken a building, a preliminary examination should be made for signs of this weakness before allowing overhauling. Where floors are heavily

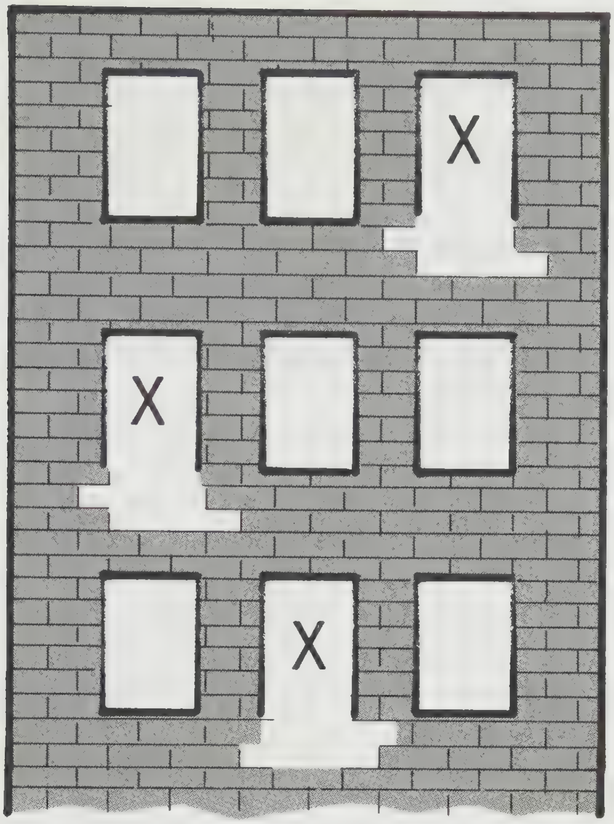


Figure 6.13. *Overhaul in large-scale fires can be expedited by cleaning out the interior and exterior wall from windowsill to floor, which permits bulky objects or other material to be more easily lowered or dropped to the street. When more than one floor is involved, the windows selected should not be in the same line.*

loaded, a space between the end floor boards and the side wall is a danger signal that the joists are pulling out of the wall.

If there is much water on the floor, it should be relieved promptly because water is quite heavy. Water an inch deep covering an area 40 × 80 feet will add about 16,000 pounds to the gross floor load. If water has accumulated on more than one floor, it should be removed from the lowest floor first and then from each floor above in turn, working from the bottom upward. This method will prevent water from upper floors adding to the load on lower floors.

Common overhauling accidents are:

1. Falls caused by firefighters stepping into holes in floors, slipping on wet or icy floors, and tripping over debris
2. Cuts caused by broken glass and metal, especially tin ceilings
3. Foreign bodies (charcoal, plaster, and so on) in eyes
4. Strains caused by lifting heavy objects
5. Injuries caused by falling objects
6. Firefighters being struck by tools wielded by others

Items 3, 5, and 6 above are most frequently caused by individuals working too close together. This problem can be easily prevented by proper supervision. It should be strongly emphasized that the duty of officers is to supervise—not to join in the work. An officer cannot properly look out for the safety of subordinates if occupied with manual work.

Another safety consideration is the presence of dangerous materials such as acids or other chemicals that may be hazardous alone or in combination. Special care is needed in handling them. Remember that containers may have been weakened by heat or water and might fall apart during handling.

Combustible dusts provide another danger. There have been occasions when firefighters disturbed dust sufficiently to disperse it with air in high enough proportions to cause a dust explosion.

A large overhauling job should be well planned. After the stability of the structure has been ascertained and danger spots noted, a procedure should be laid out so that all points will receive the necessary attention. In this way, no part of the structure will be overlooked and needless duplications are avoided. Starting and finishing points should be selected, work apportioned and assigned, and suitable tools brought to a convenient point. Adequate lighting is important for safety and efficiency.

Tools required may vary slightly with the job to be done, but the usual basic group consisting of an ax, a six-foot pike pole, and a halligan or claw tool is satisfactory for most of the work. Scoop shovels are needed where debris must be moved. Pitchforks are handy overhauling tools on certain occasions. The use of power tools, especially saws, has become popular in recent years. A common fault of small departments is not possessing short pike poles or hooks. Those with handles longer than six feet are difficult to use inside most buildings, especially dwellings.

Other overhauling equipment would include lights and a generator. Also, remember that a charged hose line or lines with sufficient hose to reach all points should be on hand. The usual practice calls for 1½-inch lines and small-capacity nozzles for easier mobility and less water damage. Pump and engine wear can be saved when hydrant pressure is adequate to supply these lines, but a pumper should be ready for instant use if needed.

Mention should also be made here of "watch lines." In extreme cases, a chief may decide that the most efficient procedure is to leave a small crew of firefighters with a charged hose line on the scene to guard against rekindle. This practice allows companies to return to quarters but is not started until routine overhauling has been completed.

The public relations aspect of overhauling is important. Unfortunately, the public seems to have an image of firefighters as housewreckers. It is worthwhile to explain the need for overhauling to the occupants of the premises, and consideration should be given to their feelings. A neat overhauling job with debris removed and a little time spent cleaning up will make a far more favorable impression than a careless job. This approach is especially true in a residence.

A good mental attitude for firefighters is to base their activities on this principle: "Suppose that I were the property owner and not a firefighter. What impression of the fire department would I get?"

NOTES

1. Fitzgerald, Robert H.: Mechanical ventilation and fog nozzles. *WNYF*, January 1958.
2. Lane, R.: *International Fire Chief*. Washington, DC: March 1980.
3. Ibid.

7

Fireground Control and Coordination

YOU DO NOT employ the same motivation techniques to drive a company of firefighters into a dirty, smoky cellar as you would to inspire the teachers at a school for girls. Many of the widely accepted management precepts which may be effective in obtaining increased production in industry have no relation to the fire service. Firefighting is not a vocation which benefits by the application of the democratic process; it most often presents an emergency situation where life is at stake and every second is of value. It is not a situation which adapts well to decision by consultation and group approval. In fact, soldiers in battle and firefighters at a fire probably represent the last work situation where autocratic command can be justified.

Many a campus Confucius has come down from an ivory tower to tell fire officers how to lead their troops. As a result, some officers are confused when dealing with the terms "fear," "respect," and "love." A few are more concerned with pleasing their personnel than with leading them. They don't seem to realize that an officer can afford to be generous only after subordinates have a certain amount of fear and respect for him. Fairness is the quality firefighters want most in an officer. Next, they want ability. After that, firmness. If the officer displays all three of these qualities, he will earn their respect. If, after establishing these qualities—but only then—the officer also shows kindness, he will receive their affection, too.

The officer who is reluctant to give orders, or who fails to be clear and definite in his orders, will lose the confidence of subordinates. People want firm leadership in an emergency. When someone holds a position responsible for that leadership, it is expected of him. That is what the officer is there for—to direct and supervise, to give orders that people are waiting to hear. If he doesn't do that job well, he will lose the confidence and the respect of his subordinates; perhaps one of them may even take over and start giving orders. If the officer forfeits his authority to this extent, he might find it impossible to retrieve. If, however, he recognizes the onset of such a situation, he can redeem himself by firmly, but calmly, asserting his authority, not so much by saying that he is boss, but by proving it.

STRESS SITUATIONS

There may come a time when an officer will have to proclaim his authority. Some firefighters react to extreme emergency situations by giving orders to others; it is their psychological response to a severe stress situation. Some people freeze, some faint, and some shout orders. If a firefighter reacts in this fashion, his officer must quickly put that individual in his place. Officers should also take care of civilians acting in the same manner. Sometimes an excited civilian who has never seen a fire before will start issuing orders to firefighters. The officer should stop this behavior quickly, either by sending the civilian on a fool's errand which will take him away from the scene, or by shutting him up. Sometimes it may be necessary to have him removed by the police.

An officer cannot afford any sign of weakness at the fire scene; on the other hand, he should not allow excitement to make him completely unreasonable. He should strive to maintain an appearance of calm and self-confidence; he should avoid high-pitched shouts and other outward signs of nervousness. Odd as it may seem, a deep-throated bellow is respected as a firm order, but a shrill shout is considered a sign of uncertainty.

A serious fire is an exciting event, and anyone who is not aroused by it is probably too stupid to understand the gravity of the situation; however, the experienced officer should be able to control that excitement. If he does, he probably will do his job well. If he doesn't, the job will suffer—and so will his reputation.

The new officer appointed as the result of a written examination should not show any feeling of inferiority when he is in command of firefighters with more seniority. He can be pleasant while being firm and can even show a slight deference to the "old timer" without sacrificing the respect of the others. It is not the purpose of this book to tell him how to adapt to his new role other than at the fire scene. There he should attempt to give enough orders, but not too many; to appear calm, but not indifferent; and, above all, to display confidence in himself and his crew.

There is an old Irish expression: "Even a pin must have a head." This adage is quite true of firefighting. There is no more disappointing or frustrating sight than that of a poorly coordinated fire attack, where the fire burns uncontrolled while firefighters or units act independently. Firefighting operations must be closely controlled and coordinated. The responsibility for direct control of a company lies with the company officer, but the task of coordinating multi-company activities rests at a higher level; it is here that the chief officers earn their pay.

The responsibility of a company officer is to see that his company does what he is ordered to do. A chief officer's responsibility is to see that the companies work in harmony to achive the common goal of putting out the fire. Oddly, one of his most important duties is to control the energies of overenthusiastic company officers. Another is to stimulate company officers who lack enthusiasm.

Overenthusiastic officers can be dangerous. They want to prove that their company is the world's best and will risk their lives and those of their crews to prove it. Firefighters have been killed needlessly in this fashion. Company pride, initiative, and even some risks should be encouraged, but not to the point of foolhardiness. Then there is the overly cautious officer. Usually, it is not the safety of his crew but his own well-being that governs his actions; he needs prodding to obtain normal performance. In the old days, this urging was supplied by a size 12 boot, but now other stimuli must be used.

Admittedly, it is difficult for any chief officer to skip around a fire to see that all companies under his command are doing what is expected of them—but that is his job, nonetheless. It helps him to know the attitudes of the company officers under his command. Who should be prodded? Who should be held back? And who can be left alone with a minimum of orders and supervision? It is also his responsibility constantly to note the progress of the fire, the effectiveness of the attack, and the safety hazards to his crews. Fires have several sides. In fact, it can be said that a structural fire has a top, bottom, and four sides, as well as the inside. Supervision of seven locations by one chief officer is not easily performed.

In cases where complete supervision is impossible, the most critical areas should get the most attention. There is a compromise available to the chief officer by which he can give directions to units at the least vulnerable sectors and leave them, while he concentrates personally on the critical areas.

COORDINATION

There are certain principles of firefighting which a chief officer must adhere to if he is to carry out his functions properly. These principles dictate:

1. Ventilation should generally not begin until hose lines are charged and ready for use at all points where ventilation might spread the fire.
2. Hose streams should not oppose each other. When a stream from the front encounters one from the rear, the usual result is a battle in which only the fire is the victor. The place for water fights is at a tournament, not a real fire.
3. Who should advance and who should withdraw should be decided by the chief officer, not by contest.
4. Orders should be obeyed immediately. "Shut down!" means *now*, not when you feel like it.

When it is realized that he must control the timing of ventilation and water application at several points, it can be clearly seen that the chief officer has a demanding job. Ventilation may be required at the roof, the floors above the fire, and the fire floor. Water may have to be applied at several locations. If these activities are not well timed and coordinated, the results can bring more harm than good.

The main efforts of chief officers should be directed at preventing common mistakes, especially their own. They should be quick to spot opposing streams and call off the one which is less needed. They should prevent outside streams from being driven into areas where inside streams are in use. They should try, within the limits of their resources, to provide the personnel needed to accomplish the desired results and see that they are properly utilized.

Of course, each fire chief has a different resource-to-problem ratio. Some find it difficult to believe what others have to contend with, but, at least, each knows in advance of the fire what his own resources are, and he can plan accordingly.

TACTICAL ERRORS AND WEAKNESSES

Constant alertness for tactical errors or weaknesses provides a chief with what is probably the most effective means for efficient firefighting. Weaknesses on the fireground commonly result from failure to analyze the situation properly. Examples of such faulty analysis include underestimating the effects of wind, the exposure hazards, or the speed with which fire can spread. Sometimes there is a failure to anticipate shifts in the fire, such as vertical extension through stair and elevator shafts and other vertical arteries, as well as through concealed wall spaces, ducts, and even through floors. Still in this category, there can be neglect of possible horizontal extension through open or weak fire doors, unprotected openings, party walls (from the beam ends of one building to the beam ends of the next), through holes in walls, through adjoining cocklofts, and over roof parapets. Fire can also extend downward, as when embers drop into shafts or combustible materials stored in yards or adjacent properties. I once saw a fourth-alarm fire in a lumber yard that was started by brands dropping from the third-floor windows of an adjacent tenement.

Effects of Air Movement

In addition to concern over wind direction and velocity, a chief must also be alert to a possible change in wind direction. Such change

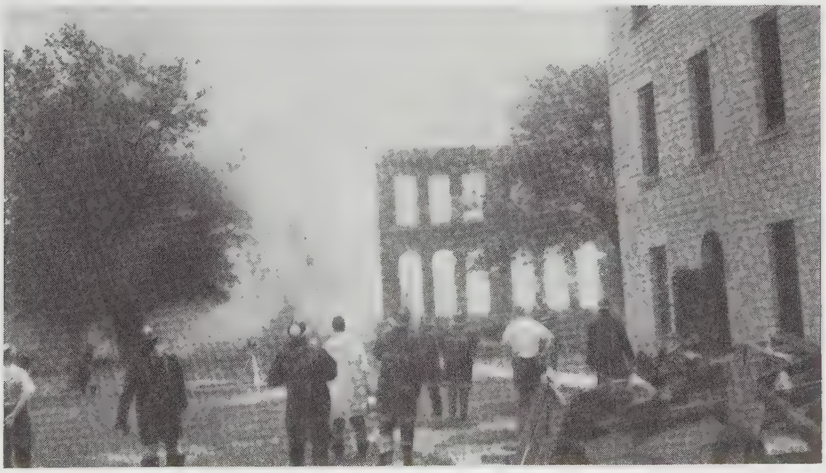


Figure 7.1. *A collapsing wall creates an artificial wind by rapidly displacing a tremendous amount of air that intensifies fire in the same way as a bellows used on burning logs. The white area in the background is flame created by the falling wall.*

can happen quickly—with as much as a 180-degree shift. Wind also comes into play when fire burns through a roof; it intensifies the fire which, in turn, becomes a threat to exposures.

A collapsing wall as it falls creates its own wind by rapidly displacing air in tremendous quantity. The artificial wind thus created intensifies and expands a fire in the same fashion as a bellows used on logs (Figure 7.1). It increases the threat to exposed structures—even those across a fairly wide street. A collapsing roof or floor has a similar but somewhat lesser effect. These matters are discussed in a later chapter under structural considerations.

Lack of alertness is evidenced by failure to protect other structures or places against fire extension caused by convection, radiation, conduction, flying brands, or explosion. The most commonly encountered fire extension is that within a building, usually from the convection of heat.

Tactical errors which permit fire to travel unchecked within a building involve the improper placement of hose lines (Figure 7.2), insufficient or improper ventilation, failure to use or augment built-in protection when it is present, and lack of adequate search for fire extension.

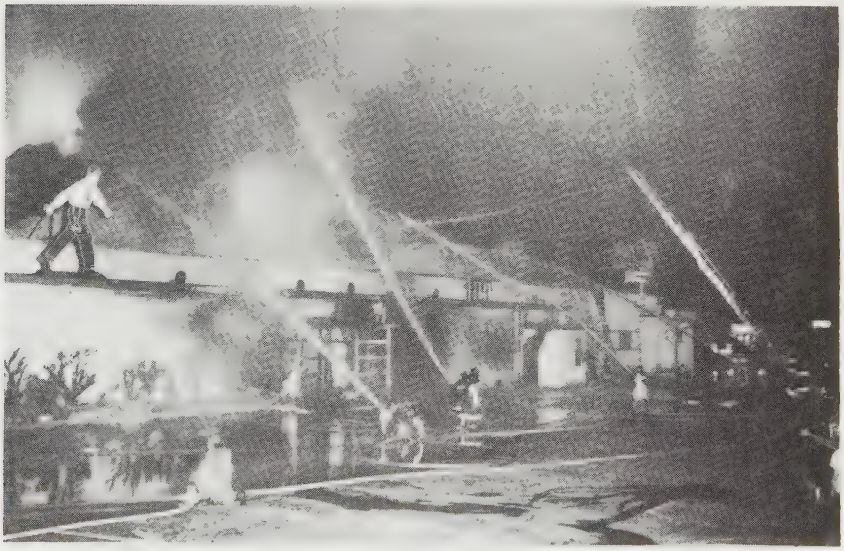


Figure 7.2. *Ineffective hose streams: At least five of the six streams shown here are not extinguishing any fire; they are all directed at flame. There is no stream directed into the main entrance, yet a stream* (at the right) *is being directed into the vestibule.*

Lack of Direction

Vague and incomplete orders cause many of these fireground failures, and they are often compounded by vague and incomplete—or nonexistent—reports of actions to the chief who gave the orders.

Lack of initiative provides another cause for fire expansion or extension. There are officers who will not take an obviously required action without a direct order and, on occasion, will not even request permission to take it. The situation worsens when these officers fail to notify their superiors of the need for an action.

Chief officers—in fact all officers—must not be afraid of causing damage. Such fear can often lead to greater damage. On occasion, a reluctance to break windows or cut holes for ventilation has led to total loss of the structure because firefighters were kept from moving in on the seat of the fire by heat and smoke that could have been removed by breaking windows and cutting holes.

Abnormal fear of water damage has the same effect when lines that are too small or too few permit a fire to burn unchecked. And, of course, a reluctance to open floors, walls, or ceiling has led to many a rekindle in which the damage was far greater than the initial fire.

When the big, or unusual, fire occurs, some officers have a tendency to follow the habits they developed at the everyday fires. As a consequence, they start out with hose lines that are too small and then graduate to more and bigger lines. Finally they hit upon master streams—a costly trial-and-error period. Heavy stream appliances were not thought of because they are not usually used. The same is true of other special equipment, and the officer who is not in the habit of calling for additional aid will sometimes forget to do so. In a similar vein, if he is accustomed to supervising all operations at small fires, he may attempt to do so at a large fire—and the fire is lost before he remembers the principle of delegating authority.

Another outstanding weakness is the failure to change tactics when they are not proving effective. An example would be a hose stream that does not reach the seat of the fire. If it has no other function, it should be moved to another point or shut down. Its continuation is not just a waste of water, but also a waste of personnel. As mentioned previously, there are ways to determine when a stream is not doing any good. The reasons why it isn't should be determined, and tactics changed accordingly. Tactics that are not getting good results should be altered even though they may conform to recommended practice. It stands to reason that, no matter how well they are recommended, something is wrong if they are not getting results.

Certain tactics are often used even though they are manifestly bad. These include the use of opposing streams, streams directed through holes in the roof or through windows when firefighters are inside, and streams directed at such steep angles as to be ineffective.

There are further weaknesses chargeable to the failure to employ good practices. Insufficient ventilation comes readily to mind, as does the improper use of breathing equipment, insufficient illumination, lack of search for people and fire extension, and insufficient overhaul. Lack of relief for firefighters who have been subjected to punishment and fatigue diminishes their efficiency.

Personnel are not always fully used, and we see instances where six firefighters attend a nozzle while other, much-needed work goes undone. We also find crews at fires doing absolutely nothing. Both situations are brought about by the lack of direction and supervision.

In evaluating life hazard versus property loss, a fire chief must have the wisdom of Solomon. If he assigns too few firefighters to search and rescue, lives may be lost. If he assigns too many, the fire may not be stopped. There have been cases where firefighters were held back by an unwarranted fear of electricity, an overestimate of the potential for building collapse, or other threats to safety. Smoke hazards are frequently overestimated; the presence of heavy smoke should not deter an aggressive interior attack on a fire.

Many of these weaknesses can be attributed to lack of knowledge and experience, but they usually occur when an officer forgets what he knows because of excitement, or when he fails to relate his knowledge to the problems confronting him.

Many tactical errors and weaknesses happen simply because of haste. It is true that fire requires rapid action, but not so rapid that it leads to mistakes. Calm and deliberate actions according to a definite plan will reduce error and strengthen attack.

APPLICATION OF THE TACTICS

The purpose of studying fireground strategy and tactics is to facilitate their application by officers at real fire situations. The officer who understands tactics can recognize the need for them and can apply his knowledge at a fire. Although firefighting may not be an exact science, there are certain principles which should be applied until found wanting. The list of tactical considerations given in Chapter 5 may not be applicable at all fires, but each item should at least be considered; true, not much time is allowed for such deliberation. Usually, it must be done in less than a minute, but this time limitation is all the more reason for a systematic approach.

The results of the application of a tactical plan depend upon several factors:

1. The accuracy of the analysis of the fire situation
2. The feasibility of the tactics chosen
3. The ability to execute the tactical plan

When any of these factors are misjudged, the whole operation may fail. Poor judgment in analyzing the situation can result in improper tactics. The failure to employ available resources can defeat the value of a good analysis. Finally, even a well-thought-out plan based on sound analysis cannot be effective if the resources needed to effect it are not available.

The officer in charge should be quick to recognize a deficiency and take steps to overcome it. The tactical plan should be flexible enough to allow for changes in the situation and the attack. For instance, there are times when what has been determined to be a defensive situation turns into one that calls for attack, and vice versa. With some officers, there is a tendency to stay with the initial plan, regardless of changes in the fire situation that would indicate a change in tactics. Often the situation is allowed to deteriorate beyond repair before the needed change is made.

Granted that the bigger the commitment, the harder it is to change. This fact does not, however, provide sufficient grounds to compound error by failing to make a necessary change. Although an initial mistake is not to be looked upon with favor, it possibly could be forgiven. To continue with an incorrect tactic in the face of inadequate results is hard to excuse.

Division of a Job into Units

Any complex task is better performed when divided into segments, with each segment properly assigned and coordinated with the others to get the desired result. This division must be done at a fire which calls for multi-company operations. Divide the total work among the companies. Let each company officer supervise the job assigned to his unit, with a chief officer coordinating the work of all the companies to obtain the desired objective. Of course, the bigger and more complex the job is, the more it will have to be subdivided, and the greater the job of directing and coordinating becomes.

As this magnitude increases, more layers of supervision have to be inserted. There are two approaches in deciding how much is needed: one is the complexity or size of the situation; the other is the number of units being supervised. In the latter case, there is the "series of fives" sometimes followed by the military. Evidently, the feeling is that every officer should have five subordinates to supervise.

If this rule were applied to firefighting, there would be one chief officer supervising every five companies. This ratio is quite compatible with general practice in most city fire departments. The average first-alarm assignment usually consists of a chief officer and five or fewer companies.

It is the responsibility of this chief to analyze the situation, determine the objectives (strategy), select a method of achieving them (tactics), and give the necessary directions to achieve these goals. He must then supervise the work of the companies to assure not only that they are doing their work properly, but also that it is in harmony with the total effort.

In the Chief's Absence

It must be recognized that at many fires one or two companies—sometimes more—will arrive before the chief. The question then arises, "Who is in charge?" This question must be answered before an alarm is ever received. The answer calls for: *(1)* clear rules as to who will be in complete charge until the chief arrives, and the extent of his authority; *(2)* company officers who have a good knowledge of tactics; and *(3)* a general policy on the tactics to be employed prior to the arrival of a chief officer.

None of these matters should be left to chance. Confusion, and even conflict, can result if it is not clear who is in charge pending the chief's arrival. Some fire departments solve the problem by ruling that the first officer to arrive is in charge of the whole operation until relieved by an officer of higher rank. Inasmuch as any company officer may find himself in charge of the whole operation, he should know the fundamentals of tactics. When an officer takes over command, he should seek the officer who has been in charge and find out what actions have been taken, and why.

Since tactical commitments may be made before the chief's arrival, there should be some assurance that they will be compatible with what the chief would do. This requirement is generally obtained in most fire departments by broadly stated policies, some examples of which are given below:

> All hose used at structural fires shall be 2½-inch diameter, except that 1½-inch hose may be used for the first line when the fire is above the ground floor in a multiple dwelling.
>
> Unless conditions require otherwise, the first line stretched at a structural fire shall be taken to the fire by way of the interior stairs.

When such policy guidelines are observed, they will spare the late-arriving chief from the sight of everything being done contrary to the way he would want it, and save everybody from his reaction to such action.

A chief officer who frequently discusses tactics with his company officers helps to establish an understanding of what he would like to find upon his arrival. In large cities, company officers who are detailed or transferred to an unfamiliar territory should attempt to find out how the battalion or division policy in that territory differs from the norm. For instance, the type of construction and arrangement of buildings in the area might call for more immediate attention to exposure protection, or there may be an established but unwritten policy regarding the position of the second-due engine.

Positioning Units

The positioning of companies—and to some extent their duties—may vary from city to city, depending on local conditions. Some cities have alleys in every block; some have none. In some cities entire blocks are lined with buildings and the only way to reach a backyard is by going through one of the buildings.

A common practice in many cities is to have the first-due engine respond to the front of the building and the second-due engine go to the rear by way of the alley. The wisdom of this practice is questionable. For one thing, it encourages opposing streams, a common error which finds two companies driving heat and smoke toward each other, with the result that neither can advance. Fire chiefs would do well to conduct studies to discover how often the second-due engine company might have been better used elsewhere than at the rear of the building.

On the other hand, there are many times when the second-due ladder company should go to work at the rear of a building. There may be someone at a rear window in need of rescue. There may be a rear fire escape which provides quick access to the roof and upper floors—and there may be a need to ventilate rear windows. Also, the ladder officer can determine if a hose line is needed at the rear and so advise the officer in charge. Sometimes only smoke is visible from the front, while actual fire might be showing at the rear.

It is not necessary—and often impossible—for a ladder company to take their apparatus to the rear of a building. But in some cases they may have to take portable ladders with them.

The positioning of companies at a multi-company operation should naturally vary with the situation, but yet remain in keeping with the principles discussed in other chapters.

Getting Ahead of the Fire

At most fires, one hose line is all that is needed to confine and extinguish the fire. At some fires, one hose line will be used to extinguish the fire and another to guard against the spread of the fire. Then there is the less frequent fire that requires many lines to control. The officer who directs the placement of hose lines should consider the following factors:

✱***Can one hose line extinguish the fire?*** If so, the first line should be used for that purpose, but not from a position that may spread the fire. If one line cannot do the job, then the first line should be used to protect the area most vulnerable to fire spread. If that line can be used on the fire at the same time, so much the better.

✱***Where is the fire most likely to spread?*** For instance, in a one-story taxpayer with several stores, the probability of the fire spreading horizontally through the cockloft is great. The first line should be used to hit the fire because that line might extinguish it before lateral spread takes place. The second and third lines should be taken into the stores on either side of the one on fire. In these adjoining stores, ceilings should be opened to find and attack any fire that may have already reached that far. Evidence of fire in the ceiling would indicate that another line be taken immediately to the next store, and so on and on. It is essential that the hose lines get ahead of the fire.

In multi-story buildings, the top floor and the floor above the fire are the two places most vulnerable to fire spread (Figure 7.3). If the fire shows symptoms of spreading, those points require protection with hose lines. Particular attention must also be given to vertical arteries such as stairs, elevators, dumbwaiters, light and air shafts, utility chases, and ventilation ducts.

✱ ***From which direction should the attack on the fire be made?*** There are three major considerations in selecting the point of attack. The principal one is that the hose stream might extend the fire (by pushing it ahead) if the stream doesn't extinguish it immediately. This danger should be avoided. The next consideration is the ease and speed with which water can be brought to bear on the fire. The third is safety—both to occupants and firefighters.

These three needs can conflict with each other. For instance, when there is an intense fire in the rear of a deep store, should the attack start at the rear where it might push the fire throughout the store? Or should the first hose line be taken in through the front of the store to avoid spreading the fire while attacking it? Theoretically, the second approach (from the front) is the better, but when the store is very deep and filled with smoke and heat, the line from the front may

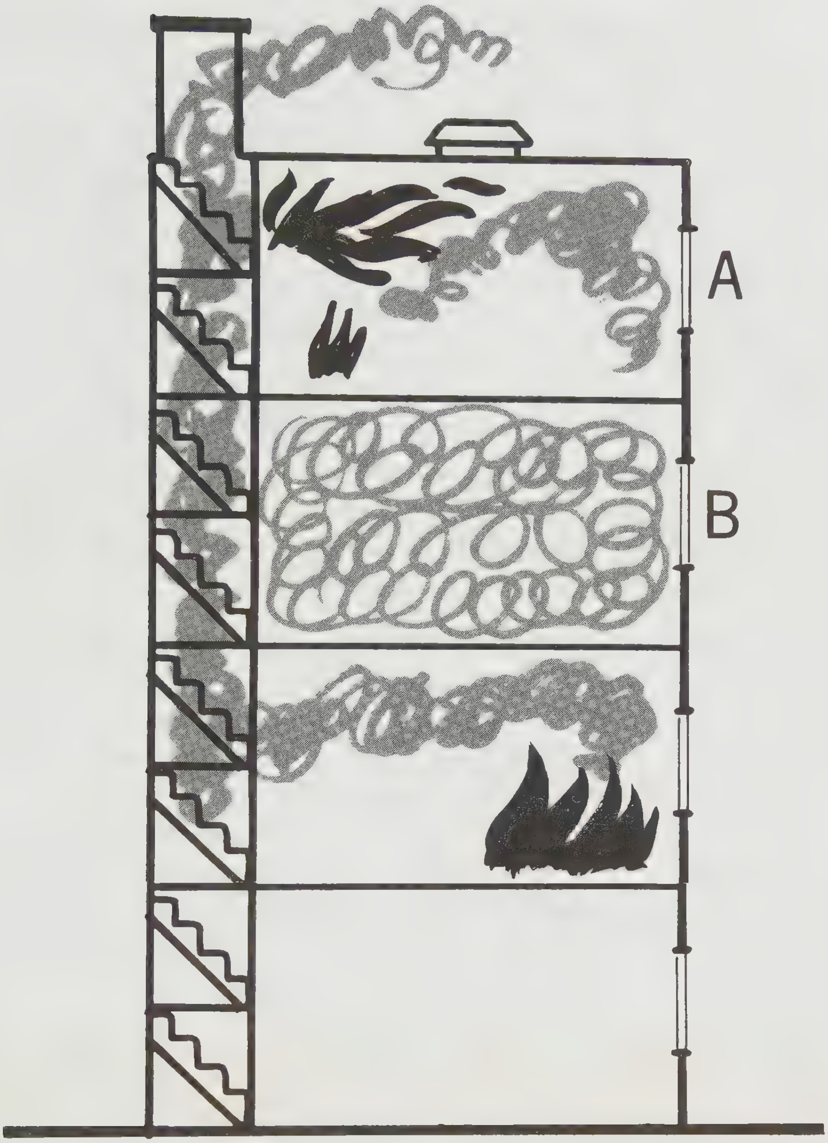


Figure 7.3. *The areas within a multi-storied building that are most vulnerable to the spread of fire are the top floor and the floor above the fire.*

take so much time to reach the fire that it may flash over the whole store before the stream can reach it. Then firefighters would be jeopardized, and the whole store would probably be lost. The line at the back door might have been able to knock down all the fire quickly and easily, but how could this fact have been known?

Such a problem could be approached by striking at the fire via the quickest avenue available, but only if it is definitely known that the stream will be able to hit the fire, reduce its size, and eliminate the possibility of it flashing over the entire store. The chances of a rear attack spreading the fire forward can be minimized by using a straight

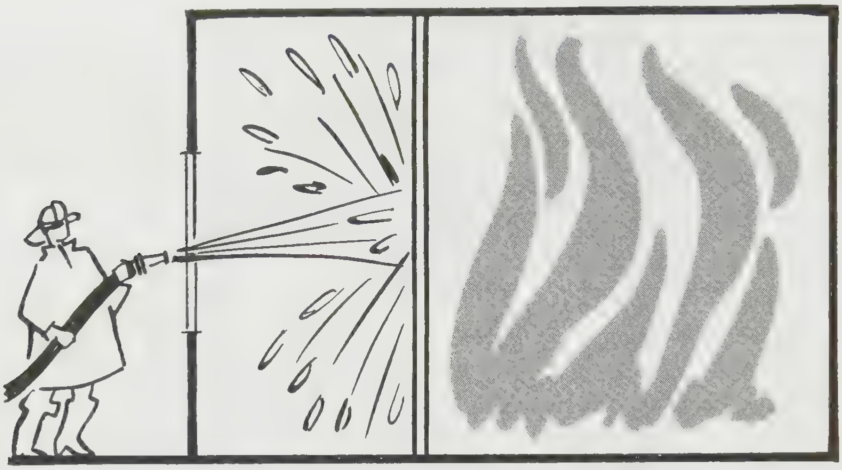


Figure 7.4. *A stream might have adequate volume and pressure and still be ineffective—for example, when it strikes a partition, just inside a window, that blocks it from the fire.*

stream and aiming it at the ceiling in as vertical a position as practicable. Such a position reduces the forward movement of heat and fire gases carried with the air currents that are created by the stream. If the rear attack is not immediately successful, firefighters should switch to the front.

The line at the front should be moved in as soon as it becomes apparent that the first line has not succeeded. Remember that both lines should not operate at the same time unless it is decided that neither can advance and that exterior firefighting is called for. In this case, as soon as it appears that the building can be entered, the line opposite the one entering should be shut down.

Another consideration in selecting the point of attack is the direction of air currents to the base of the fire. Fires often have an "intake" side and an "exhaust" side. If the attack is made from the intake side, the firefighters will have fresh air moving with them toward the fire. If they attack from the exhaust side, they will, in effect, be bucking the flow of heat and smoke.

At a multi-storied building, the attack is usually made from the stairway regardless of the convenience of other means. If attack from the stairway is impossible, then the first line becomes a defensive line: it keeps the fire out of the stairway while the attack is made from a fire escape or other avenue.

This tactic is commonly employed at cellar fires where there is an interior stairway which would permit the upward travel of fire. If the fire is so intense that a line cannot be taken down the stairs, it is held at the top of the cellar stairs while another line enters the cellar from an exterior entrance. This second line will drive much heat and smoke up the interior stairway, but the firefighters there must hold their position to prevent upward extension of the fire. They should not close the door leading to the cellar nor open their line into the stair. Either of these tactics threatens the firefighters below. They should remain low and permit the heat and smoke to pass over them. If actual fire appears, they will have to hit it, but they should try to hit it by bouncing their stream off the stair soffits, so that less heat is driven back into the cellar where other firefighters are trying to advance.

Since a hose stream moves heat and smoke, outside streams should not be directed into areas of a structure where firefighters have entered or are trying to enter. Violation of this principle has resulted in firefighters getting burned, lines being abandoned, and fire being driven through a building.

It is unfortunate, but true, that inexperienced or untrained officers are inclined to aim streams at flames wherever they show. All too many times we see pictures of streams from hand lines—but more often, aerial pipes—that are directed into roof openings, thus nullifying the beneficial effects of roof ventilation (Figure 7.5). Such streams

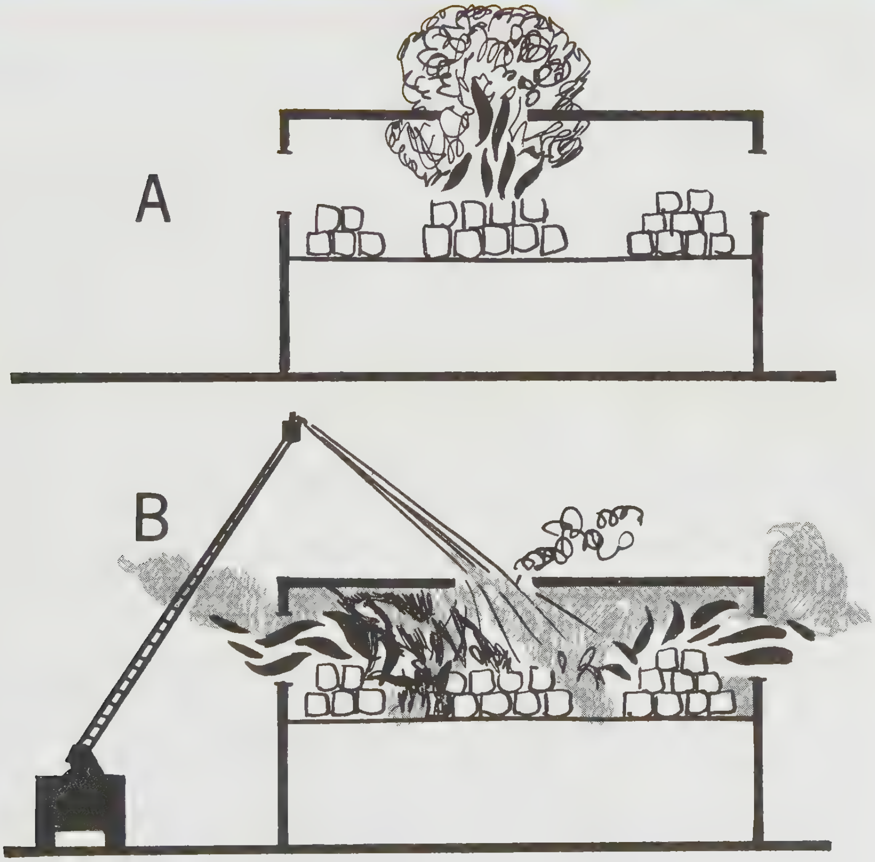


Figure 7.5. *A properly made hole cut in the roof for ventilation (**A**) has its beneficial results nullified by improperly used stream (**B**). Such streams act as a cover which arrests ventilation, drives fire to the other parts of the building, and often drives firefighters out of the building.*

not only act as a cover which arrests ventilation, but also drive the heat and products of combustion back into the building, with the twofold result of driving the firefighters out and spreading the fire.

Similarly, when fire is exhausting up a shaft, a stream directed down the shaft will reverse the flow of heat, smoke, and gases, driving them back into the building (or buildings, if the shaft serves more than one building, such as a light and air shaft). Streams protecting against fires in shafts should be aimed upward or horizontally, not downward.

An infrequent, but valuable, use of a hose stream is the protection of escape routes for occupants of the fire building. Although this practice may be rarely invoked, it should be kept in mind. An example, which occurred in a division where I worked, was at a fire in a tenant factory when many workers were exiting from above the fire by way of a rear fire escape. An engine company placed a nozzle in the fire floor window that opened on the fire escape, set the nozzle on the wide angle fog position and closed the window. This maneuver kept the window glass from breaking, and the heat and smoke from obstructing the fire escape. After all persons had safely passed the fire floor, the nozzle was shut down and the window opened to allow the interior streams to advance unhampered.

The company officer in charge of an individual hose line is responsible for its effectiveness, but the chief officer in charge of the total scene has the responsibility of coordinating all hose stream operations. He should know how to orchestrate their use in harmony—shutting down one, adding another, repositioning them as needed, and in general working them toward the desired objective.

Exposure protection is not often needed or used, but when it is needed, it is of extreme importance. For that reason, if no other, it is a matter that must be diligently studied. There are more factors to consider than just the likelihood of ignition of another structure.

For example, if a fire threatens an abandoned building and a hospital, the hospital must be protected first—even if it is the farthest building from the fire (see Figure 7.6). Loss of the hospital with its occupants and equipment would be tremendous. It would take an interminably long time to evacuate the hospital, and even then the evacuated patients would have to be relocated. Such tasks as hospital evacuation and patient relocation are fraught with problems, which could be solved by eliminating the need to evacuate the hospital. Therefore, it can be seen that top priority for exposure protection should go to the hospital.

Even after the hospital has been taken care of, the building which comprises exposure 4 may have to wait. Suppose building 2.1 con-

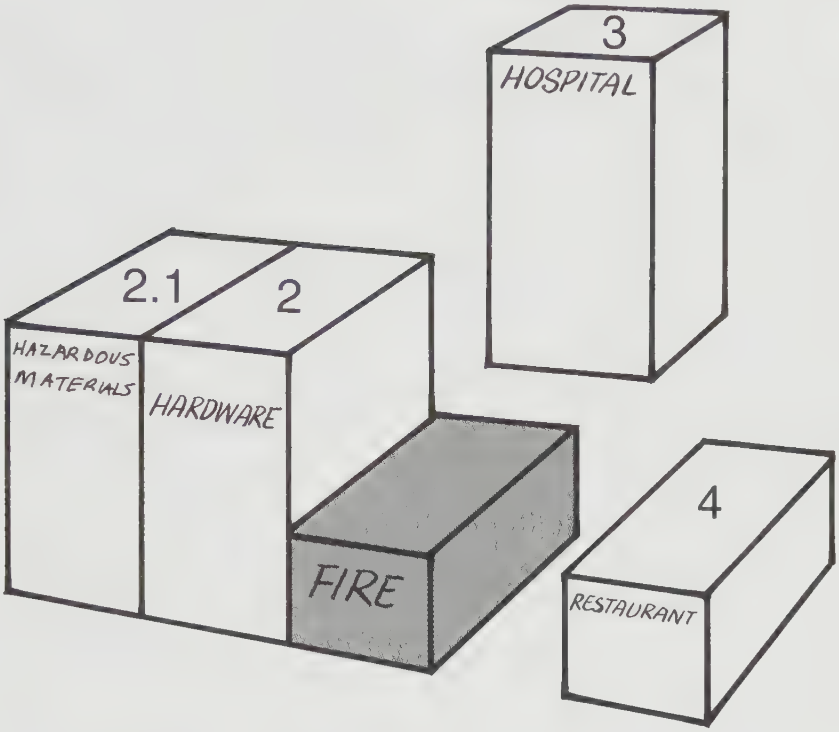


Figure 7.6. Which exposure deserves the most attention? Exposure 2 is not greatly endangered, but there is a possibility of extension of the fire through floor beams abutting those in the fire building. Exposure 3, while not nearest the fire nor the most threatened, should get top priority because of the life hazard. Exposure 4 is most threatened—it would have windows facing the fire building—but it is less important than exposure 3. Exposure 2.1 could cause a disaster by explosion or the possible release of fumes.

tains highly hazardous materials. If the fire extends to them, it may cause an explosion of great force or perhaps the liberation of toxic fumes over a large area. The point is clear: exposure protection should not be based just on proximity to the fire or probability of fire spread. It should be determined by the ultimate effects on life and economy.

Summoning Aid

The officer in charge at a fire is occasionally confronted with the problem of deciding when to call for help. In addition to using the ideal-rate-of-flow formula prescribed in earlier chapters, he may consider the progress of the firefighters compared to the progress of the fire. If the fire is making better progress, then help is needed, as indicated in Chapter 6.

Coordinating Ventilation

Ventilation of a fire building should get a high priority. The officer in charge should check all desirable points for ventilation, starting with the roof, to make sure that none has been overlooked. He should note how effective the ventilation is, and take steps to improve it—by mechanical means if necessary. He should note the effect of the wind and the direction of air flow to and from the base of the fire. He should see that ventilation is done in harmony with hose line operation; it should not be performed prematurely (before the nozzle is charged and in position to attack the fire).

A type of ventilation which is seldom discussed in print is sometimes the final remedy to a ventilation problem at a large fire. It is effected by allowing the fire to burn a large hole in the roof of the building, where there is considerable fire on the top floor of a building and it is unsafe to put firefighters on the roof to cut holes. The change in fire behavior when the fire burns through is remarkable. Windows and doorways which had been outlets for flames become fresh air inlets. Halls and stairs which were untenable become relatively free of heat and smoke. Handlines can be advanced into the building to extinguish the fire.

To effect this unusual type of ventilation, streams into the top floor are restricted, if not shut down entirely. Usually this type of ventilation is so good that, if the building is still structurally sound, handlines can finish the job within and heavy streams can be discontinued. The change in condition can be noted from the street level by observing when flames at windows diminish. This change indicates that roof ventilation has begun to be effective. (See Figure 6.8.)

Use of Flooding

Another tactic that is seldom discussed, but is sometimes effective, is flooding. There are different types of flooding used as a last resort at stubborn mercantile or industrial fires. (It should never be necessary to use flooding in dwellings or multiple dwellings.) One method is the "floor above" flooding. Here, water in considerable quantity is flowed on to the floor above the fire so that it acts as a somewhat random sprinkler system, which attacks the fire below by running down wall spaces and pipe recesses and between the cracks in floors. This method can be more effective if baseboards are removed along the walls to make it easy for the water to go into the wall spaces. Water then not only attacks the fire but prevents its upward spread. In connection with this method, it is sometimes good to remove the baseboards early in case flooding may be resorted to later, after the floor has become untenable. To reduce water damage on the floor above to a minimum, place nozzles or open butts on the floor where they will not hit stock or furnishings.

Another type of flooding saturates the top floor of a building with heavy streams so that the water will run down through wall spaces and floor cracks from floor to floor to extinguish inaccessible fire in walls and ceilings.

Total cellar flooding is called for when the probability of structural collapse would make entry too dangerous. Open butts achieve this faster than nozzles, but it is still a time-consuming process. For instance, in a store cellar measuring 20 × 90 feet, with a ceilng eight feet high, there are 14,400 cubic feet. If one-third of this volume is occupied by stock, there are 9,600 cubic feet to be filled with water—about 72,000 gallons, or 1,200 gpm for an hour, or 2,400 gpm for a half hour.

A saturation technique somewhat akin to flooding is the prevention of upward extension of a fire by keeping the temperatures on the floor above the fire below the ignition points of its stock and components. This technique calls for keeping them wet or preventing heat build-up at the ceiling, or both. Heavy spray streams can be used effectively if they have sufficient reach or are used in conjunction with straight streams. This technique is sometimes resorted to in stores when there is a large fire in a basement that has one or more open stairways leading to the first floor.

Flame Behavior

It is important that a chief, when directing and coordinating fire streams, be alert to those that are not getting good results and that he be aware of the possible reasons for this ineffectiveness. It is an acknowledged fact throughout the fire service that water should not be applied to smoke alone. This practice only serves to complicate the problem by cooling the smoke and gases so that they don't rise and escape by ventilation. It is not widely known, however, that the application of water to flame is not always effective. There are times when the visible flame is far from the fuel source, and the water applied to it is useless.

Such a condition is not as rare as may be thought; if it isn't recognized, a lot of harm can result. For instance, a fire department responded to a rural fire and, upon arrival, found flames emanating from a basement window. They applied a fog stream from a 1½-inch hose line into the window, and the flames disappeared, but when they shut the line down, the flames reappeared. This process was repeated until they ran out of water and the house burned down.

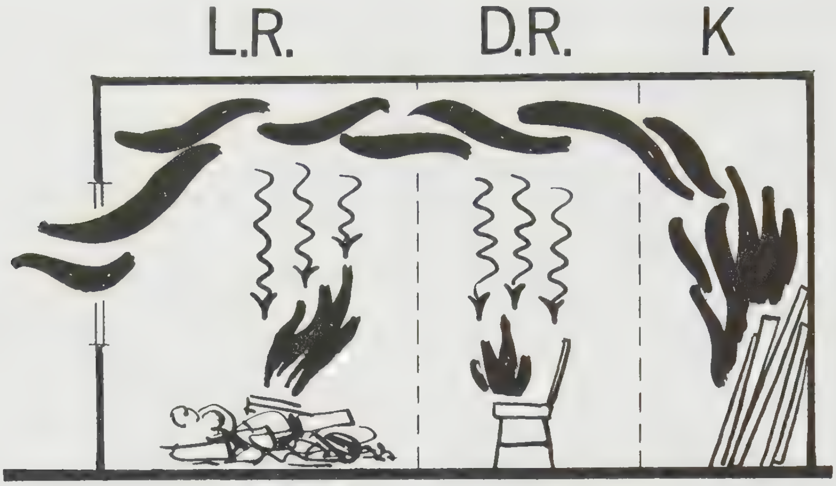


Figure 7.7. *At a test fire, a pile of scrap wood was ignited in the kitchen (K). As the fire developed, the flame spread along the ceiling, through the dining room (D.R.) and living room (L.R.) and finally out through a living room window. Heat radiating from the flame ignited a chair seat in the dining room and rubbish on the living room floor. The flame going out the living room window is from the wood in the kitchen.*

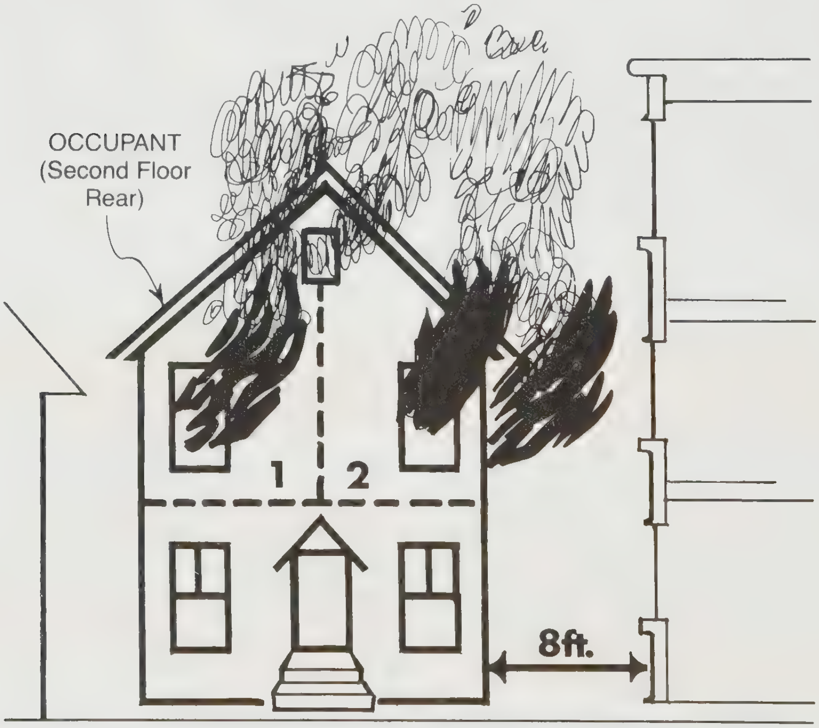


Figure 7.8. *Any fire officer may be suddenly forced to make decisions of the utmost importance. In this example, the lieutenant of the first company to arrive must decide how to utilize the limited resources available. The building on the right is a block-long factory that employs a large percentage of the town's work force. It is severely exposed by a fire in the nearby house, where a person is trapped at the rear of the second floor. The lieutenant had better be prepared to make correct decisions instantly.*

In another case, an arson investigator asked me for advice on a fire that puzzled him. The fire had originated in the kitchen of a large restaurant after it was closed for the night. The fire department confined the fire to the kitchen, but every chair seat in the dining area was burned, although there was no other burning in the dining room.

Another case occurred in a supper club where there appeared to be two separate fires: one in the bar area (where the fire originated) and another in the dining room.

An experiment we conducted at Camp Douglas, Wisconsin, showed what actually happened in all three of the above cases. There, we started a fire in a pile of scrap wood in the kitchen of a dwelling that had two other rooms on the ground floor. We left open a door that connected the kitchen with the dining room. The dining room opened on to the living room. As the fire developed, the flames from the kitchen spread through the doorway and along the under side of the dining room ceiling, then across the living room ceiling to a window and out the window. Since heat radiates from a flame in all directions, the heat radiating downward from the flame at the ceiling set fire to the seat of a chair in the dining room and some rubbish on the living room floor.

At this point, a fog stream was directed into the window of the living room where flame was coming out. The flame immediately went out, but returned when the nozzle was shut off. After we repeated this procedure a few times, we moved the line to the other end of the building. Here we directed the stream only into the kitchen. When this was done, the flame retreated from the window, across the ceiling of the living room, then the dining room, and then disappeared. The rubbish on the floor of the living room and the seat of the chair in the dining room continued to burn, however, as they were now separate fires and not dependent on the fuel (and heat) source in the kitchen (Figure 7.7).

Here, one test gave the answer to what had happened in the restaurant, the supper club, and the basement of the dwelling. Therefore, remember that water application to flame may not extinguish the fire; the water should be applied to the fuel source. Such rolling of flame under the ceiling is sometimes called "rollover."

Partitions within a building and piles of stock often block streams that would otherwise reach the seat of a fire, and these must be somehow circumvented.

Another deficiency that should be guarded against is the tendency of some officers to continue operation of a stream that has done all the good it can. This practice not only increases water damage, but also keeps several firefighters from doing needed work elsewhere. Even worse, it may be fanning the fire it doesn't reach.

8

Safety on the Fireground

ONE OF THE leading causes of fireground injuries is adrenaline. In another word: excitement. Give a group of firefighters a simulated situation, and they will go through the exercise with nonchalant ease, performing duties efficiently and without injury. Turn it into the real thing and their attitude changes dramatically. Mistakes are made and injuries occur.

When they are working without the emotional stress of the "real" fire, they are ten times more observant, five times more cautious, and much more effective. Also, their pulse rates are lower, their air supply is used less rapidly, and they expend less energy.

Furthermore, the emotional stress factor can adversely affect direction and supervision. Officers may not perform these tasks efficiently when excited and this reaction, too, can lead to injuries. In fact, supervision is the key to improving safety on the fireground. One of an officer's chief responsibilities is the safety of his subordinates. Unfortunately, the reduced staffing levels of companies have relegated the officer to working as a firefighter in many cases. When he is thus occupied, his ability to protect his crew is impaired. He is less able to discover hazards and prevent unsafe acts. Rather than having one safety officer in the department, all officers should be safety officers.

Another important duty of any officer on the fireground is to keep track of his subordinates. If they are out of his sight, he should at least know where they went, and he should have a list of their names on his person or in the cab of his vehicle. (The latter is better, should he himself become a casualty.) When subordinate individuals or groups are working in a hazardous situation, they should not be forgotten, but monitored frequently. There have been many cases of a firefighter getting into serious trouble without being missed.

During the decade of the nineteen eighties, we have seen a marked increase in emphasis on the safety of firefighters. Four NFPA (National Fire Protection Association) standards dealing with safety were developed, and the U.S. Department of Labor, through its Occupational Safety and Health Administration (OSHA) promulgated rules affecting firefighter safety.

It is claimed that firefighting is the most hazardous occupation in the United States. The very nature of the job connotes danger. If fire didn't produce a hazardous situation, the fire department wouldn't be called. From the time the alarm is received until the fire scene has been secured, the firefighter is exposed to risks far above average. For instance, upon receipt of the alarm, he may have to slide down a pole quickly to get to the apparatus floor. Many men have been seriously injured while doing this. Next, he must ride a large vehicle as it hurriedly maneuvers through—and against—traffic. Then he must work at a fire.

Studies show that a fair proportion of firefighter injuries are received at activities other than those at the fire scene: responding to or returning from alarms, training, physical fitness programs, fire station duties, and other work. These activities are not within the scope of this book. Therefore, I will concentrate here on safety upon the fireground and attempt to analyze how and why firefighters are hurt there, so that safety can be improved with the beneficial result of fewer deaths and injuries.

During the eighties, the pattern of fireground fatalities has remained consistent. There were about 50 such deaths per year, with approximately half due to heart attacks. Thus, about 25 firefighters die from trauma of various kinds, including drowning and electrocution. Unfortunately, the problem doesn't receive adequate study. The only in-depth investigation was made for the International Association of Fire Fighters (IAFF) over a 15-month period, ending in December 1975. While one could say that this report is dated, it is still valid and quite consistent in its broad findings with the statistics of the following ten years. But it goes far beyond dry statistics and reaches into on-site investigation to tell not only what the firefighter died of but how, why, when, and in what kind of structure.

It also shows that both experience and age are important factors. The younger firefighters were killed traumatically; the older ones suffered heart attacks. Firefighters with less than five years' service had no fatal heart attacks, but 14 died of trauma. Conversely, those with 21 to 25 years' service had 14 fatal heart attacks but only three deaths by trauma. Another finding was that firefighting is most dangerous in the northeastern states, and least so in the Far West and Northwest. Interestingly, this information pertains not only to the traumatic deaths, but also to the heart attacks. Four states—Massachusetts, New York, Ohio, and Pennsylvania—had 47.5 percent of all deaths. But by far the greatest number of heart attacks occurred in New England, which experienced 14 compared to zero in California, Arizona, Hawaii, and New Mexico, although the population of IAFF members is higher in the latter group. Are New England winters the reason? Evidently not; the five northwestern states bordering Canada reported only one heart fatality. Perhaps the difference is due to different firefighting problems or methods or perhaps to more fire duty. The fire incidence is very high in the Northeast. Note also that this study covered 15 months and reported 28 fatal heart attacks. The NFPA reported 23 such deaths on the fireground in 1988, indicating no change in 13 years. Heart attacks still kill almost as many firefighters as all other causes combined.

The next leading causes of death in the IAFF report appear to be:

	Incidents	*Deaths*
Building collapse	9	11
Burns	5	12
Smoke inhalation	5	8
Electrocution	4	5
Falls	2	2

We won't attempt a transcription of this excellent report. We will instead condense and interpret it in a way that will identify the basic reason for the accident as the cause, rather then the attributed cause. If one firefighter died from asphyxiation while trapped in a building collapse, we will give the cause as building collapse. If another died from a building collapse caused by an explosion, we will give explosion as the cause.

BUILDING COLLAPSE

The report shows 16 deaths from 11 incidents of building collapse but two of the incidents, taking five lives, were precipitated by explosions. Let us look more closely at the nine deaths caused by the collapse of some part of a fire-weakened structure.

1. Auto body shop, 45 feet by 97 feet, concrete block walls with brick veneer, steel truss roof: Three walls collapsed five minutes after arrival. Victim was inside.
2. Church, 60 feet by 80 feet, wood walls: A wood-truss-supported tin roof, which collapsed ten minutes after arrival. Man died inside, pinned by beam.
3. Log kiln, 26 feet by 152 feet: Concrete block wall collapsed on man outside about 20 minutes after arrival of department.
4. Auto dealership, 125 feet by 125 feet: What is described as a wood, arch-truss roof collapsed five minutes after arrival, pushing out a wall, which fell on a man outside.
5. Commercial occupancy, 60 feet by 50 feet: An hour after arrival with the fire still out of control, the chief noticed a crack in the brick rear wall. He warned the men to back away, but it collapsed on them, killing two in the yard. The steel truss roof then fell, pushing out a side wall.
6. Factory, double-brick front wall, concrete block sides, 65 feet by 150 feet, wood roof supported by five-inch by eight-inch wood beams: The brick front wall fell out about 40 minutes after arrival, falling on a man outside.

All of the above were one-story buildings, and four out of six had truss roofs (Figure 8.1), two of which were steel. In two cases, the victims were inside; in four, they were outside.

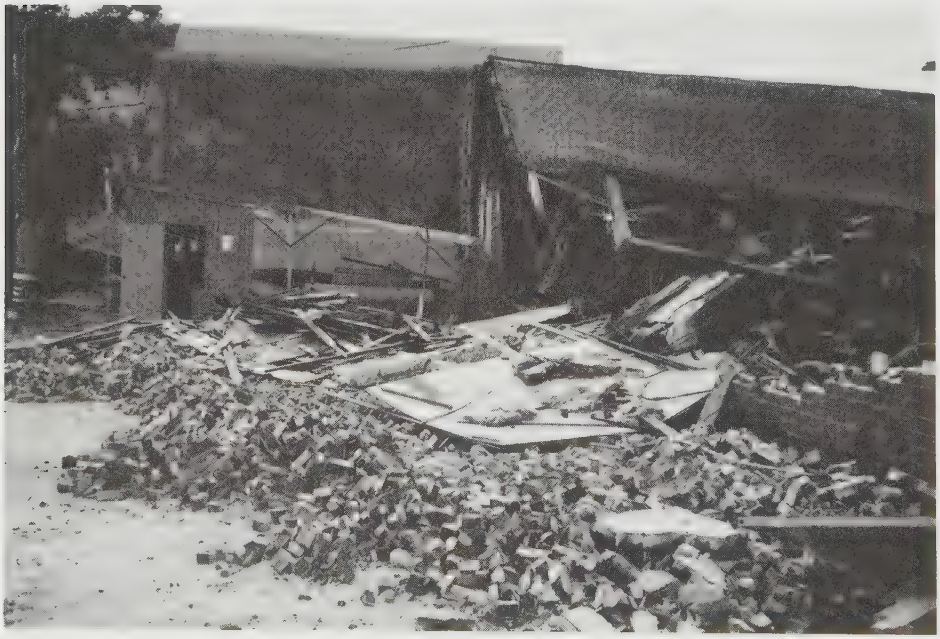


Figure 8.1. *When "bowstring" roof trusses collapse, they may force the side walls to fall outward, as happened in the case shown here.*

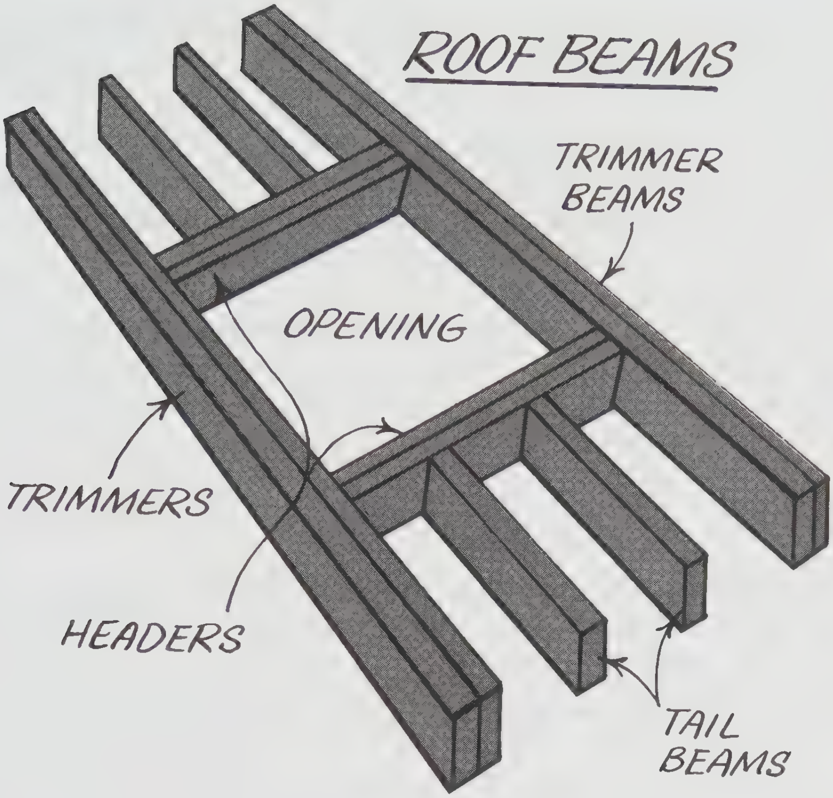


Figure 8.2. *In a wood joist building, the construction around roof openings, such as that over stairs or elevators, provides the thickest beams on the roof, which often remain after others burn away.*

When the first edition of this book appeared in 1973, we warned firefighters about truss roofs and even gave illustrations, but we didn't expect that the warning would be reinforced so graphically two years later—and it has been reinforced every year since, with unfortunate consequences.

It is interesting to note that, of all those killed by the collapses described above, none was on the roof and in only two cases were they under it. Most of them were outside, so we shall repeat here the warning we first sounded in 1973 that the walls are often the greatest danger in a truss roof building and in other one-story structures as well.

7. Two firefighters were killed in a two-and-one-half-story wood-frame structure which had been abandoned for three years. During that time, lumber and plumbing had been stolen and a previous three-alarm fire had taken place there. In this case, the firefighters had darkened the fire and moved from a ladder into the attic when the roof and the attic floor collapsed (Figure 8.2).

There were two deaths attributed to falls, which I would blame instead on structural failure.

8. A small portion of a plywood roof gave way, and a firefighter fell into the fire below and died of burns.
9. A very small section of floor collapsed, dropping a firefighter into the fire below, where he died of burns.

Thus, we have nine cases of limited or extensive structural failure induced by fire without explosion, and two cases of explosion-caused structural collapse. No cause of explosion was given.

BURNS

1. A firefighter with protective clothing and breathing apparatus was caught by flashover while operating a booster line in a dance hall.
2. The next case was attributed to a backdraft but appears to have been a traveling flashover, which occurred about 15 minutes after arrival. It looks as though the fire flashed over on the first floor and went up the stairs to catch the firefighter, who was assisting an occupant on the second floor. He was wearing protective clothing, which limited his burns; however, the breathing apparatus facepiece was off when he was found. The building was a hotel.
3. Eight firefighters died in one incident, which accounts for most of the burn deaths in the report and raises burns to second place among fatalities. They were killed about 34 hours after the start of a refinery fire, when an area of spilled oil suddenly ignited, even though it was apparently covered by foam.
4. The victim was working from a ladder at the open top of a sawdust hopper, when the sawdust in suspension ignited rapidly.
5. A semi-trailer tank truck, carrying 7,100 gallons of gasoline overturned. Firefighters were using two 1½-inch hose lines to disperse the spilled gasoline when it ignited.

SMOKE INHALATION

Many people reading firefighter death statistics make the erroneous assumption that the smoke victims failed to wear breathing apparatus. In fact, the opposite is probably true. In the report under discussion, eight firefighters succumbed to "smoke inhalation." Five of them were wearing self-contained breathing apparatus (SCBA) but ran out of air. Two of the others had taken their breathing apparatus off. Only one of the fatalities had entered a building without such protection.

1. This case was most unusual in that a volunteer firefighter died when he ran out of air in the basement of a building in which he both lived and worked. He was unable to escape when his low-air alarm sounded. Fellow firefighters outside heard his bell and, by shouting, guided him to a small window, but he couldn't get through because a floor joist was too close to the opening. They were unable to pull him out.

2. Two firefighters with SCBA died when they ran out of air. One SCBA had a warning bell; the other did not. They apparently entered the large building to search for the fire and became lost. It is said that they were not missed until about an hour after they had entered.

3. The victim was not wearing breathing apparatus, but everyone else was. He was a driver who had entered the building unknown to the others.

4. The fire occurred in a store and went to complete involvement of the store but not of the basement. After extinguishment, a company entered the basement to find and close the gas shutoff. They had previously searched the basement, found no fire and only a slight haze of smoke at the ceiling, so this time they did not wear breathing apparatus. Five were overcome, and two of them died in the hospital. The cause of death was attributed to carbon monoxide believed to be from the fire. (Tests have shown that although CO is lighter than air, it can be forced downward in wall spaces by rapid expansion following the line of least resistance.) It may have remained in the basement because that was much cooler than the fire floor above.

5. Two men perished when they ran out of air at a fire on the fourteenth floor of a 22-story apartment building. Evidently, the fire flashed over in the apartment of origin, and the flashover traveled down the hall. The victims took refuge in another apartment and apparently were not missed. The cause of death was given as carbon monoxide poisoning.

ELECTROCUTION

Five firefighters died from electrocution at four incidents.

1. Two firefighters were about to lower a 35-foot metal extension ladder when taking up after a major fire. It was dark, and as they pulled the ladder away from the building it hit an 11,000-volt wire. They died instantly.
2. A firefighter was atop a metal aerial ladder at the edge of the roof of a three-story building. What actually happened was not seen, but it is believed that his back touched a 7,200-volt wire that ran parallel to the building.
3. The victim was fighting a grass fire when he stepped on an unseen 7,200-volt line that had fallen and started the fire.
4. A forestry fire crew responded to a brush fire caused by a fallen 12,000-volt line. The victim was alone when he came in contact with the line, so it is not known exactly how the death occurred.

These case histories are illustrative of a variety of hazards facing firefighters and are probably typical of most of the fireground fatalities. They are offered here because of the lessons afforded as well as to examine a typical year. It may not be typical to include the eight burn victims at the refinery fire, but the other events are repeated annually. Although it is difficult to break down with precision the most recently available figures, our attempts seem to indicate that the percentages in the fatality categories have remained about the same over the years. The non-fatal injury percentages remain constant also.

Two other important discoveries from the report were that the vast majority of deaths occurred at commercial occupancies, and most happened at night. It is apparent, too, that most deaths occur at multiple-alarm fires.

Our studies of other reports from states and larger fire departments indicate a general agreement with the NFPA annual injury statistics, which show that, of all fireground injuries, sprains and strains account for about 27 percent, cuts and bruises 24 percent, smoke or gas inhalation 16 percent, and burns about 10 percent.

In one large fire department, the leading ways in which injuries were incurred were (by percentages):

Overexertion	20
Struck against	13
Struck by	13
Fall from elevation	5
Fall from same level	12
Burns	10
Smoke inhalation	3

In another department, we see what the injured were doing when they got hurt (by percentages):

Hose operations	28
Ventilating	14
Directing operations	12
Overhauling	5
Rescue operations	3

When Denis Dewar was the Florida fire marshal, he reported that, on an injury per 100 fires basis, the most dangerous occupancies were: manufacturing, basic industry, hotel, storage, stores and offices, and public assembly (based on 507 firefighter injuries throughout the state).

The purpose of studying the causes of fireground deaths and injuries is to gain knowledge to prevent them in the future.

SAFETY AND BUILDING COLLAPSE

The next chapter will discuss structural stability, collapse potential, and warning signals. Inasmuch as the victims of structural collapse are often on the roof of the building and not easily able to see the signs—if any are visible—of impending collapse, it is well to advise them of the safety precautions to observe while working on a flat roof (the type of roof to worry about).

First of all, if the roof is built up (wood boards covered with tarpaper, felt, tar, and maybe gravel) and it feels spongy when walked on, it has been weakened by fire. This reaction does not mean it will collapse, but it does mean that the roof is suspect. The spongy feeling usually signifies that the roof boards, but not necessarily the beams, have been weakened. (If, however, the roof is a metal deck on bar joists, it will be resilient to begin with, and will give the feeling even without a fire.)

There is a place on a flat (built-up) roof which is somewhat safer than the rest of the roof, if part—but not all—of the roof collapses: on the trimmer beams. When there are openings in the roof, such as the top of a stair shaft or other shaft, or a skylight or scuttle opening, such openings are surrounded by header beams at each end, and trimmer beams on each side. Because the headers support the weight of the tail beams, they are reinforced. That load is then transferred from the headers to the trimmer beams, which require extra strength and thickness to carry the load. The thickness keeps them from burning through as quickly as other roof beams. Often the rest of the roof will collapse, but the trimmers will remain in place. If firefighters are working on a fire-weakened roof, it is well to bear this fact in mind. Standing on the trimmer beams might save a firefighter from dropping with a falling roof joist.

The truss roof is the type most prone to early collapse. This type of roof is described in the next chapter on structural considerations. It is dangerous to put firefighters under or on such a roof when there is strong probability that the trusses have been subjected to heavy fire. There is also the hazard of firefighters being struck by the walls pushed out when a truss fails; such failure usually pushes out side walls rather than those at the front or rear. Therefore, the sides are more dangerous locations when a truss roof collapse occurs.

SAFETY AIDS

There are other safety precautions worth considering for work on flat-roofed buildings. One of these would be a regulation that requires a company ordered to work on a roof to take ropes and safety belts or harnesses with them for possible emergency descent. (A rope can also be used to bring up tools, hose, or other equipment.)

A ladder raised to a roof offers another safety aid. If the ladder is raised at least five feet above the roof, it can be seen by firefighters on the roof who are looking for it when in a hurry to get down (Figure 8.3). Furthermore, such a position makes it easier to step on or off the ladder. Other than to save a life, it is bad practice to remove a ladder that could be needed for escape.

WORK ON PEAKED ROOFS

Peaked or gable roofs on dwellings offer another safety hazard to firefighters. Generally they don't collapse, but fire from below can burn through these roofs to cut off escape, and their slope increases the possibility of a firefighter falling to the ground. If the roof is made

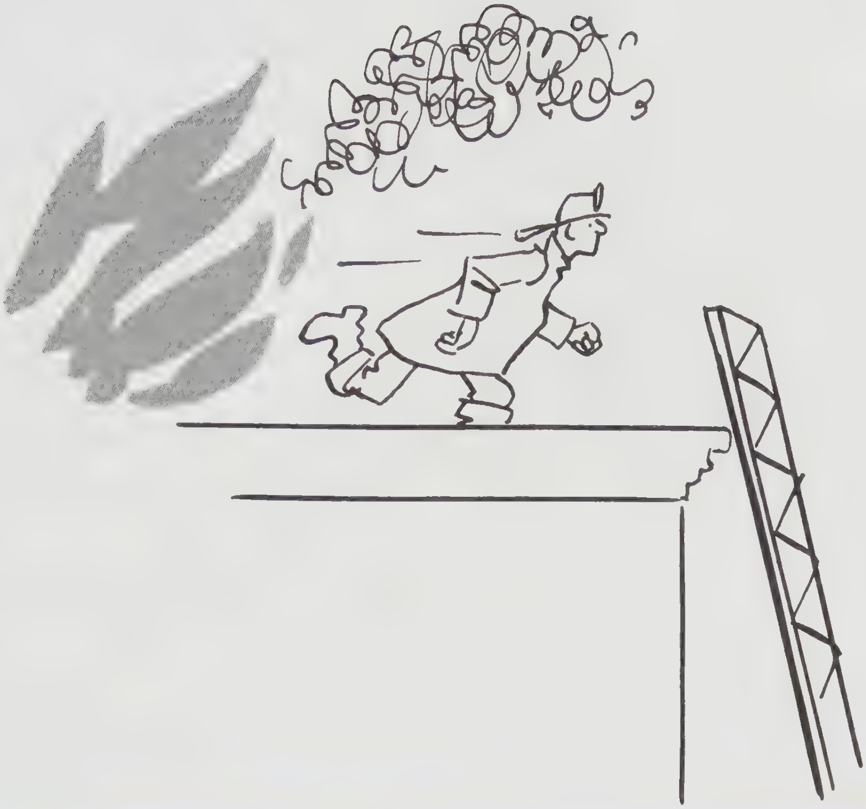


Figure 8.3. *Aerial or ground ladders, when raised to a roof, should have the tip extending five feet above the roof line. Such positioning provides firefighters with an easily visible and accessible escape route when needed.*

of wood shingles, a portion of it might suddenly light up in flame from fire in the attic, perhaps cutting off escape to a ladder. No matter what the roof shingles are made of, when an attic fire bursts through a hole cut in the roof, it may shoot a column of flame several feet into the air, and the radiant heat from the flame may burn nearby firefighters if they can't get away quickly. It is never wise to cut a hole between the firefighter and an escape route, and it is a good practice for the one cutting a hole in a roof to face away from the wind, so that the wind would blow erupting heat away from rather than toward him.

Gable roofs with a steep slant are a safety hazard because firefighters can lose their footing, slide down the roof, and fall to the ground. The first man I ever saw killed died of this cause. This hazard is particularly bad when the roof is icy or wet; it is worse with slate shingles, but bad enough with wood, or even composition shingles if

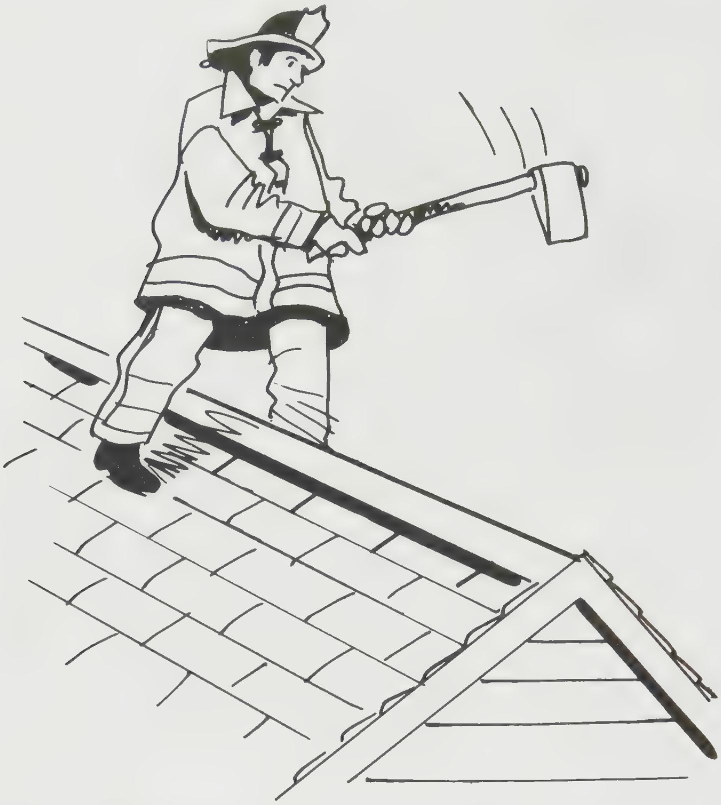


Figure 8.4. When working on a pitched roof, firefighters should try to straddle the ridge; this position affords the best guarantee against falling.

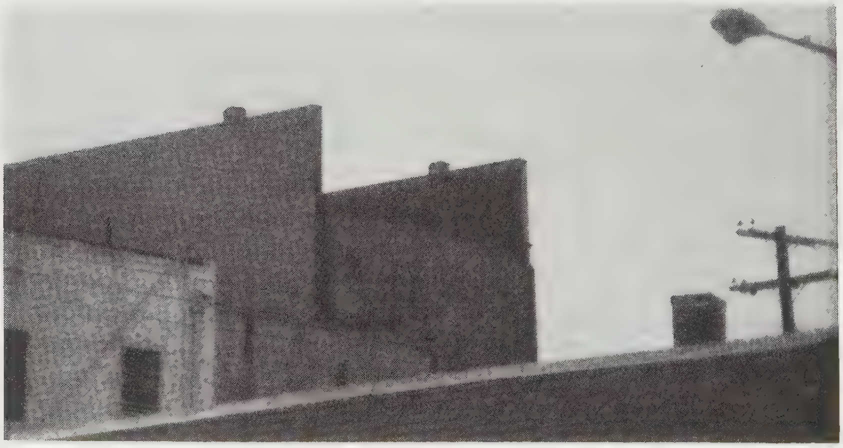


Figure 8.5. Appearances can be deceiving. A firefighter stepping off a ladder placed against the wall of this building would have a fall of almost 12 feet. It is best to keep a firm grip on the ladder until solid footing is assured.

the roof pitch is steep. Rubber-soled boots give a much better footing on these roofs than leather-soled shoes or boots. Firefighters wearing leather boots with leather soles and heels are quite likely to slip and slide.

It is a good precaution to use a roof (hook) ladder to climb up a sloping roof after the hooks have been secured over the peak, but sometimes the roof ladder is too short to reach all the way to the peak. In that case, two can be used; the first is pushed up into place by the second, which is then hooked onto a rung of the first.

When working on a roof peak, a firefighter may straddle the peak with one foot on one side and one on the other (Figure 8.4). This way he can walk along the ridge and, if he slips, he will probably fall in a "split" position on the ridge, which may be awkward and possibly painful, but is better than falling to the ground and suffering death or serious injury.

USE OF SAFETY BELTS

The use of the safety belt or similar approved equipment should be stressed, especially when members are working on ladders. It is dangerous to operate a hose line from a ladder without using a safety belt. The safety belt can also be valuable during a ladder rescue if the rescuer starts to slip, lose his grip on the victim, or becomes fatigued. If the rescuer has on a safety belt, he or she can hook on to a rung of the ladder and use both hands to hold the victim safely until help arrives or the rescuer is rested enough to continue carrying the victim down the ladder.

LADDERING DAMAGED STAIRS

Stairways eaten by fire have collapsed, causing the deaths of firefighters. If only a flight or two appears damaged and the damage seems to be confined just to the treads and risers, a ladder can be laid on the stairs to keep firefighters from falling through. If, however, the structural support of the stairs is weakened, it would be well to use outside ladders and fire escapes.

Before overhauling a building that has been subjected to much fire, an examination should be made to determine its stability, as detailed in Chapter 7. Water should be removed, and care taken in knocking out walls to facilitate overhaul.

RESCUE CARRY

The "fireman's carry" is good when walking or crawling on a level surface, but it is not the ideal way to carry a person down a ladder. On a ladder, the position of the victim tends to cause his or her weight to pull the rescuer away from the ladder. A more practical position from the firefighter's standpoint is the "cross chest, through the legs carry." In this method, the rescuer can keep both hands on the ladder at all times and can rest by leaning on and pressing the victim against the ladder (Figure 8.6).

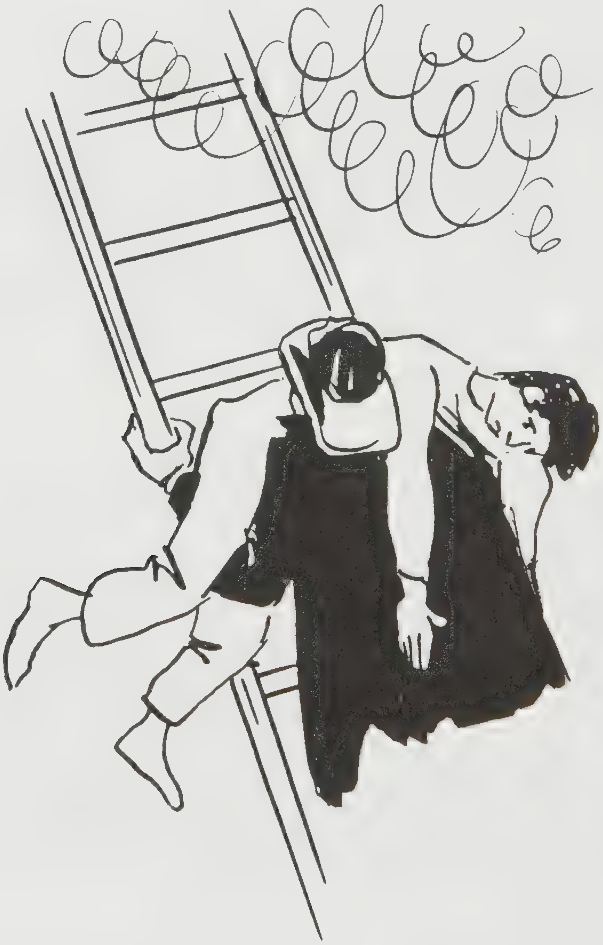


Figure 8.6. *The cross chest carry is the safest to use on a ladder. The firefighter can hold the rescued individual against the ladder to rest or readjust the hold and also has both hands free to grip the ladder.*

SMOKE—A HIGH HAZARD

The most frequently encountered safety hazard at fires is smoke. Smoke in this context means not only the visible carbon particles and tar bubbles, but the hot gases in which they are suspended. The gases which result from combustion and the vapors distilled from fuel sources are mostly invisible, and the most dangerous of them, carbon monoxide, is also odorless and tasteless; it is the most dangerous because it is a common product of combustion, given off whenever a carbonaceous material is burned. There are gaseous products of combustion that may be as dangerous as carbon monoxide, but they are not encountered as frequently or in such quantity.

Nature provides warning signals against carbon monoxide by making the carbon and tar particles extremely irritating to the eyes and respiratory passages. Thus it is difficult, but not impossible, for a person to endure smoke long enough to be affected seriously by the carbon monoxide. There have been test fires where the carbon monoxide reached as much as 10 percent of the atmosphere at a point five feet above the floor (on the fire floor)—an extremely high reading. Ordinarily, the carbon monoxide in smoke does not exceed 2 percent. A firefighter can endure a level of 2 percent for about two minutes without collapse, but in some cases collapse could occur sooner. It depends on the breathing rate, which in turn is influenced by exertion and stress. There is a rough formula which states that, when the time in minutes is multiplied by the percentage of carbon monoxide in the air, collapse will occur when the product reaches 4.5. Thus, a carbon monoxide percentage of .45 could be tolerated for ten minutes, and so on, but don't count on it. This combination of time and percentage is why building occupants die at a fire where firefighters survive: the firefighters are subjected to the same level, but not for as long a time.

Another danger to firefighters is lack of oxygen. Human beings need a level of about 16 percent oxygen in the atmosphere for continued existence; they can survive on smaller percentages but not for long. Flame will not exist without 16 percent oxygen; therefore the presence of flame is an indication that there is enough oxygen to support life.

Combating Smoke

There are three methods of protecting firefighters against the toxic and irritating products of combustion. One is prompt and proper ventilation to reduce the percentage of carbon monoxide and increase that of oxygen. The next is to relieve personnel frequently when they are working in smoke. This procedure reduces exposure time and stops the build-up of carbon monoxide in the blood. The third method is by the use of respiratory protective equipment, which is now a required safety precaution in most jurisdictions.

Protective breathing equipment is not new to the fire service. Many American fire departments used the Lacour Respirator in the 1870s; it was a self-contained unit, consisting of a large canvas bag which was inflated by a bellows after being put on the wearer's back. It was claimed that the supply of air forced into the bag could last for 40 minutes of hard use. There was a leather facepiece connected by tube to the bag. Probably the main reason this equipment was discarded was that the wearer had to suck air out of one tube and exhale through another, a feat which probably required most of his attention.

At any rate, the Lacour—and also the Neally respirator, a filter type—had disappeared from American fire departments by 1900, and the early days of this century saw very little use of breathing apparatus at fires. Rescue companies in some of the large cities carried European-made oxygen rebreathers (as some do today), but these devices were regarded as highly specialized equipment to be entrusted only to the specially selected and highly trained squadmen.

Then, filter canister masks which could remove the irritants from the smoke and convert carbon monoxide to harmless carbon dioxide became popular. By 1960, they were widely used by American fire departments. Unfortunately, they had the double deficiency of needing at least 16 percent oxygen in the atmosphere (because the filter merely filtered; it did not supply oxygen), and of not being able to convert high concentrations of carbon monoxide. Inasmuch as several deaths and many injuries were attributed to these deficiencies, this type was withdrawn from general firefighting use in 1971.

The big advantages offered by the filter canister type of gas masks were their light weight, small size, ease of donning, and long duration of use under most conditions. These are desirable characteristics, none of which is found in presently used breathing apparatus. The most popular American breathing apparatus now is the open-circuit, compressed-air demand type which has proven dependable, but is bulky and takes time to put in operation.

Mask Limitations

Experiments show that firefighters get a certain amount of leakage of the facepiece with most breathing apparatus. Results in the field, however, seem to discount any great danger from this source, and positive pressure in the facepiece further reduces the hazard.

BREATHING AIR CONSUMED
(CUBIC FEET PER MINUTE)

SMOKE DIVERS' COURSE, FLORIDA STATE FIRE COLLEGE

TASK NAME	1	2	3	4	5	6	AVE.
Anderson, Wm.	1.85	3.07	1.91	1.71	1.70	1.59	**1.97**
Conti, R.P.	1.80	4.09	2.30	1.68	1.71	1.77	**2.23**
Emrich, Rev. R.L.	1.82	4.09	2.34	1.76	2.14	1.78	**2.32**
Franklin, R.S. III	1.29	1.03	2.34	2.04	1.94	1.65	**1.72**
Grant, R.D.	1.90	4.09	3.00	1.91	2.19	1.76	**2.48**
Hayden, J.T.	1.53	3.58	3.00	2.76	2.05	2.10	**2.50**
Hutchinson, K.	3.52	4.60	3.02	1.92	2.47	2.34	**2.98**
Johnston, J.F.	1.57	2.05	2.02	1.96	2.08	1.97	**1.94**
Kempert, L.	2.16	3.58	3.79	2.60	3.10	2.03	**2.87**
Nadeau, L.P.	2.10	3.07	3.00	1.59	1.91	2.03	**2.28**
Raymond, Wm. H.	2.66	2.55	3.07	1.66	2.10	1.90	**2.32**
Riggs, J.H.	2.39	2.55	3.07	2.19	2.14	1.70	**2.34**
Royal, H.S.	2.18	1.03	3.07	2.00	1.88	2.01	**2.03**
Sherman, G.A.	1.80	2.55	2.55	2.96	2.63	2.01	**2.42**
Smith, R.C.	1.82	3.07	2.55	2.22	1.85	1.92	**2.24**
Westbrook, M.E.	2.14	2.55	2.55	2.87	2.16	2.33	**2.43**
AVERAGE	**2.03**	**2.97**	**2.72**	**2.11**	**2.13**	**1.93**	

TASKS
1. Walk up tower and return.
2. Chop wood (2 minutes).
3. Carry hose pack and nozzle to top of tower and return.
4. Down tower from top through maze—no smoke-obscured vision.
5. Maze with smoke.
6. Search and rescue, heat and smoke, fire test building.

Figure 8.7. *Comparison of the use of breathing air.*

The greatest danger to a firefighter wearing reliable self-contained breathing apparatus is that of using up all the air (or oxygen) while still in a contaminated atmosphere (Figure 8.7). This danger has been lessened somewhat in recent years by the addition on the air tank of alarm devices which sound when the air supply reaches a predetermined low level. These devices are, however, set to give a few minutes' escape time at normal air consumption. A firefighter must re-

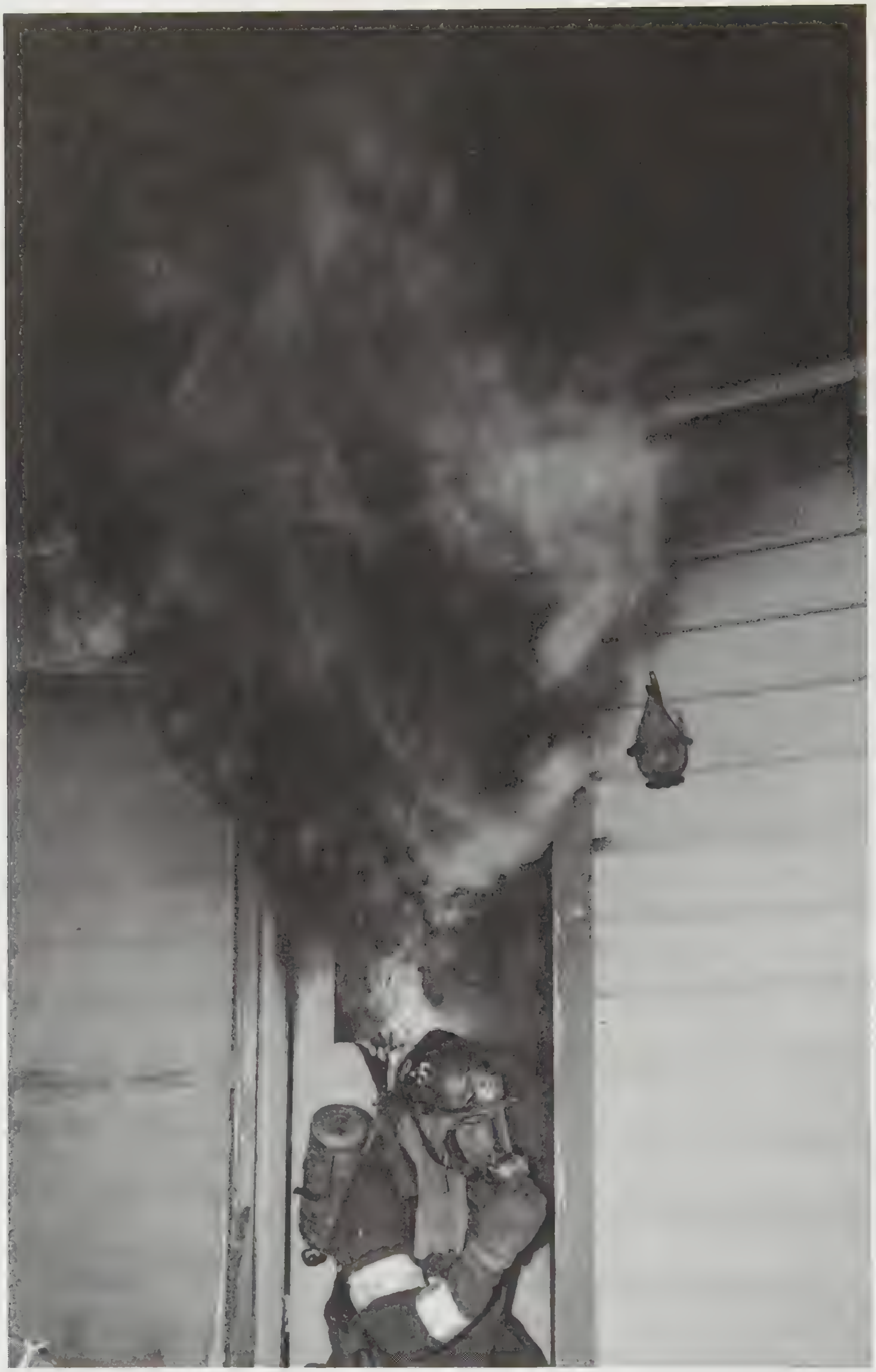


Figure 8.8. *Even the simple act of opening a door should be performed carefully. It could precipitate a flashover, a backdraft, or a vent-point ignition.*

member that, if he is consuming air at a rapid rate, his escape time will be lowered considerably. This time is especially critical if he is deep within a building, vessel, or tunnel, far from the nearest exit to safety. I have seen cases where the remaining air was consumed in less than two minutes after the alarm sounded.

Firefighters need intensive training under realistic conditions to learn the limitations of breathing apparatus and themselves. Each crew member should know his or her own rate of air consumption and be guided by it in determining safety precautions. Instead of waiting for the alarm to sound, the firefighter should read the pressure gauge frequently. The alarm could fail to operate, or the rate of consumption could be so great that there would be insufficient time for safe escape.

Thorough training in the use of breathing apparatus under conditions approximating those found at fires is necessary for several reasons. It helps the firefighter adjust to working in such an environment, to become familiar with wearing the breathing apparatus, and to learn how to control breathing in a way that will make the air supply last longer (Figure 8.9). A well-trained firefighter can get almost twice the time as an untrained one from the same amount of air.

Some deaths and injuries have resulted from firefighters removing the facepieces of their breathing apparatus in moments of panic when they felt they were not getting enough air. With older models of breathing apparatus, it is possible for the wearer to demand more than the regulator will supply. The remedy is to stop working, calm down,

Figure 8.9. *Masked firefighters were exposed to temperatures as high as 760 degrees F (at shoulder level) for 12 seconds without ill effects in smoke divers' course at Florida State Fire College. Without breathing apparatus, they could only take 560 degrees F for the same interval. This test was in dry air; humid air would not permit such exposure.*

?

and rest until respiration becomes normal. With some firefighters, the cause of panic is more psychological than physical; even so, the same remedy would apply.

It is rare for fire departments today to require firefighters to use tag lines, i.e., a rope attached to the wearer and monitored by someone outside the danger area. Such a rope can become entangled around obstructions and defeat its purpose. The most prevalent precaution is the "buddy" system, whereby two firefighters stay together and observe each other for signs of distress, so that one can help the other if the need arises. "Buddy breathing" is a practice whereby a firefighter who has used up his air supply hooks his tube into the regulator on his buddy's apparatus or into his facepiece, alternating with him on drawing from his air supply. When this situation arises, both should leave the contaminated area.

The English fire service instituted a system of mask safety in the early 1960s which met with considerable opposition when introduced. It called for keeping time on each firefighter wearing breathing apparatus. Many felt that this was a needless precaution which wasted time and tied up as timekeeper a firefighter who could have been otherwise better employed. Today, the system is well accepted. A firefighter is assigned as "breathing apparatus officer" and issued a "B.A." board fitted with a clock and slots to accommodate tags carried on each breathing apparatus. After a firefighter dons his apparatus, he gives the tag to the B.A. officer who inserts it into a slot and marks next to it the time when the air should expire. The officer constantly compares the clock time to that marked on the slots. If a firefighter has not reported back by the time designated, a search is started. Reports from England indicate that lives have been saved by this procedure.

In summary, of all protective equipment available to the firefighter, breathing apparatus is undoubtedly the most vital. It should not be taken for granted nor treated lightly. Personnel should be well drilled in its use under training conditions that call for strenuous work with vision obscured. The proper use of breathing apparatus can result in increased efficiency, but the improper use of it can be extremely dangerous.

HEAT HAZARD AND CLOTHING

Another abnormal and hazardous condition encountered by the firefighter is that of uncontrolled heat, which can cause skin burns, heat prostration, and damage to the respiratory tract.

Over the years, attempts have been made to protect the firefighter from heat with specialized clothing. Five important features must be evaluated in determining the heat protection afforded by a garment. These are:

Thermal resistance
Thermal capacity
Reflectivity
Flammability
Durability in high temperature

Thermal resistance denotes the ability of a material to provide a barrier which reduces the amount of external heat passing through the barrier to the body of the wearer—in other words, the insulating property of the garment.

Thermal capacity refers to the ability of a material to absorb and store heat, which is a good property until the maximum is reached; then the garment gives off heat to the wearer, sometimes rather suddenly.

Reflectivity of a material is of importance only in the presence of high radiant heat (Figure 8.10). It is based on the principle that light-colored or polished surfaces reflect more radiant heat than dark or rough surfaces. Alumimized fabrics, which reflect as much as 96 percent of radiant heat, are designed to use this reflective principle. They are of great benefit at fires where intense heat radiation is present. Flammable-liquid fires, lumberyard fires, or other large outdoor fires, including conflagrations, come under this category. Reflectivity does not help, however, against the heat of convection (hot gases) encountered in smoky interior fires.

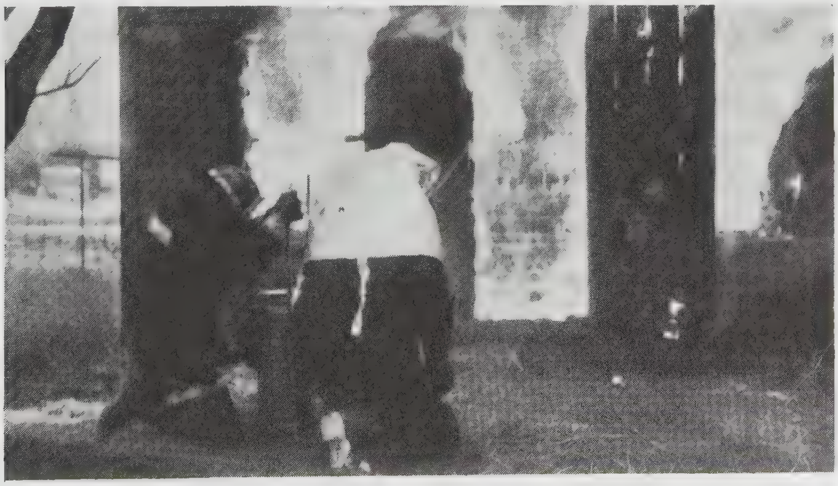


Figure 8.10. *The firefighter at the right with a reflective hood was better able to withstand radiant heat from the fire than his partner.*

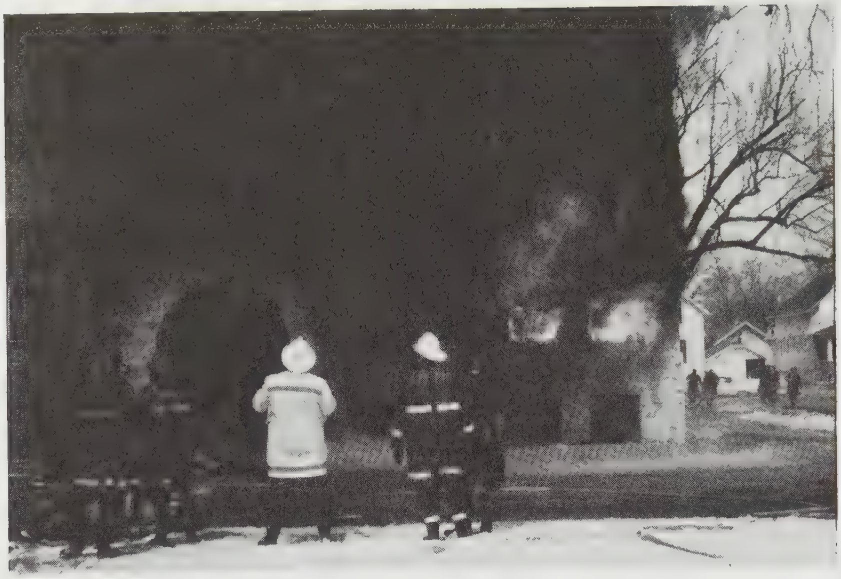


Figure 8.11. The yellow coat on the chief stands out in contrast to the black ones worn by others. Reflective tapes on the black coats somewhat increase the wearers' visibility.

It is a fact that radiant heat in the infrared range of the spectrum is reflected by shiny surfaces and not much affected by the color (light or dark) of the surface. And it is also true that most of the heat radiated from a fire is in the infrared range. Nevertheless, there is some heat in the other bands of the spectrum which are reflected by light colors. But the most important factor in light-color reflectivity is that of visibility (Figure 8.11), which will be discussed later.

Flammability signifies ease of ignition. Some materials ignite more quickly than others. The majority of firefighters today wear garments that are combustible; they will burn, but most do not ignite quickly.

Durability under high-temperature conditions is an important factor, because some garments which are not flammable may fall apart when subjected to excessive heat, losing all their protective features.

Thermal resistance (insulation) can be provided by thickness, or density of the materials used, or by air gaps provided by layering them. Some garments combine these three features. One of the disadvantages of thermal insulation is that it limits the escape of body heat. A firefighter wearing a garment that could give complete protection against external heat would collapse from heat exhaustion in about 20 minutes because his or her own body heat could not escape, and heat exhaustion is a serious matter, which can cause permanent injury to many internal organs.

CLOTHING LIMITATIONS AND PROBLEMS

Sometimes firefighters collapse because of their heavy clothing rather than their firefighting activities. On occasion, men working strenuously in hot weather, but not at all near the fire, have collapsed from heat exhaustion due to wearing heavy liners in their bunker clothing. The protection against external heat therefore is a matter that should be weighed carefully. How many times is this protection warranted, compared to the difficulties it presents? Should a firefighter wear a heavy overcoat while doing arduous work on a roof in July? Should one be dressed for the Arctic while overhauling in warm weather after a fire has been extinguished? It is interesting to note that the larger fire departments, which have the most fires, do not insist on the use of heavy linings.

Unless the inner surface of a garment has the ability to absorb perspiration readily, the wearer will suffer. Perspiration must be able to escape by outward diffusion if the body is to be kept from overheating. Absorption by the material next to the skin aids in the body-cooling process.

A water-absorbing outer surface can provide cooling through the evaporation of water on the outside of the coat, but this characteristic is only of value if there is a waterproof barrier between the outer shell and inner liner. If there is no such barrier, there is danger of scalding the skin when a wet garment is heated.

It should be realized that the human body is, in effect, an evaporator. It maintains its normal temperature through the evaporation of perspiration. If this process is interfered with, the body is in trouble. The evaporation of perspiration requires free circulation of air next to the skin. This circulation can be created by the movement of the wearer if the suit is ventilated, but such ventilation may permit the entry of hot gases.

Unfortunately, clothes which give the best protection against all kinds of heat are either cumbersome, uncomfortable, expensive, or all three. Some experiments have led British experts to declare that underwear is perhaps more important in protecting the body than outer garments are. Mesh underwear gives good protection against heat.

Physical effort in a hot environment forces the internal body temperature to rise above normal, causing the peripheral blood vessels to dilate.

Increased work and the weight of protective clothing and breathing equipment can soon drive up the body temperature and heart rate. If sweat is not evaporated, body core temperature can reach 103° F, at which point collapse is imminent. If the person sweats profusely, he or she may become dehydrated to a dangerous level. The increase in heartbeats from heat alone is enough to be dangerous and will be further elevated by exertion or emotional stress, both common on the fireground. These causes may be responsible for a number of heart failure, heat exhaustion, and heat stroke cases. (When the rate of body heat production exceeds heat loss for an extended period, heat stroke occurs, which is life-threatening and needs immediate medical help. The symptoms are hot skin, high body temperature, disorientation, confusion, and strong rapid pulse.)

Since the first edition of this book, both NFPA Standard 1971 and OSHA 1910, subpart L, as well as some state OSHA agencies have set forth requirements for protective clothing.

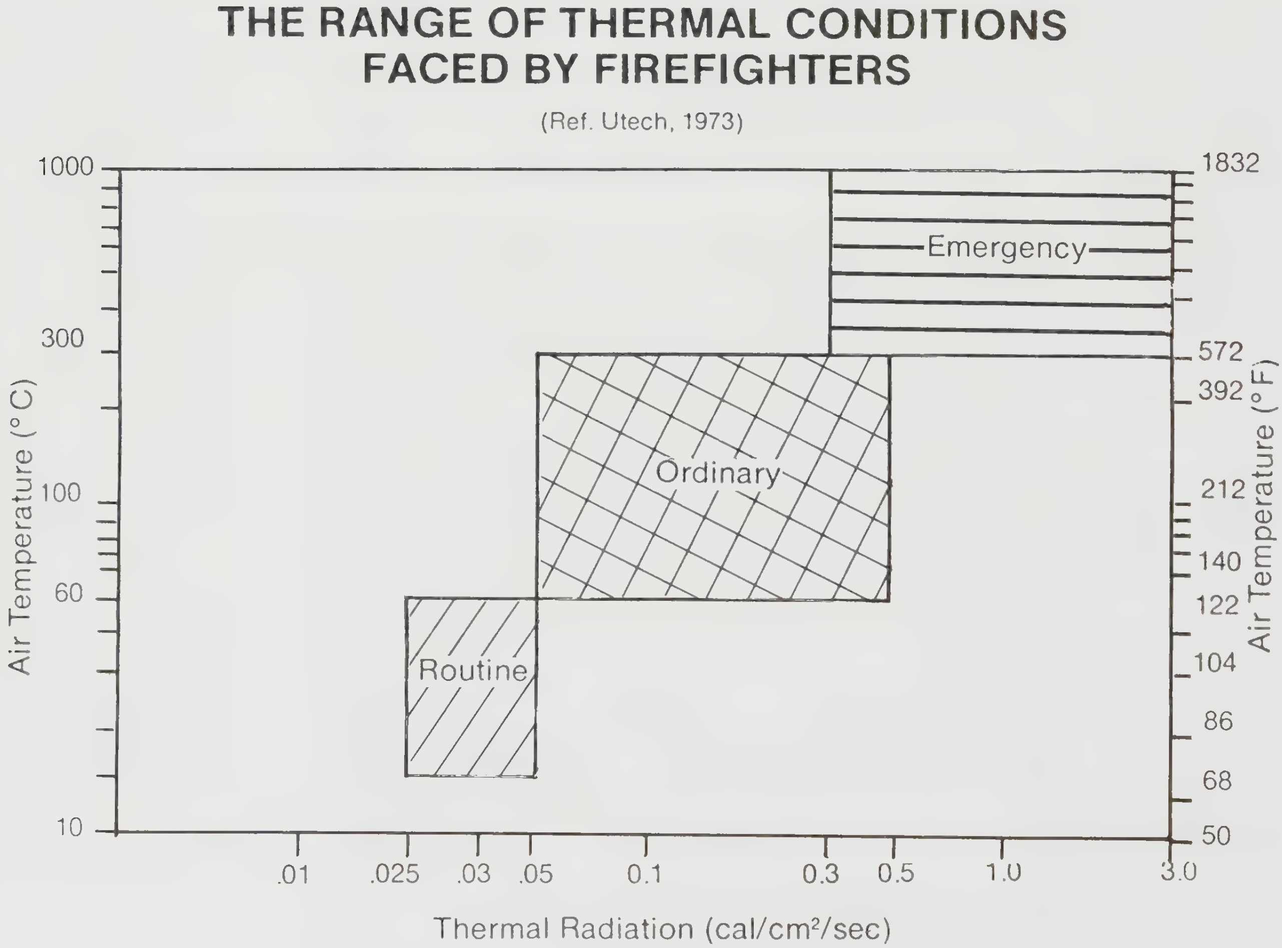


Figure 8.12. Dr. Harvey Utech, one of the first scientists to do research on heat hazards to firefighters, developed this table, which has been used to design protective clothing.

Requirements are based partly on the work done by Dr. Harvey Utech at the U.S. Bureau of Standards. Utech divided interior fires into three categories, according to severity of thermal radiation and air temperatures. His chart, later modified to reflect additional data, is shown in Figure 8.12.

Firefighters should be taught that their protective clothing is not fireproof. The outer shell of the garment is required to give only 15 seconds' protection against flashover temperatures, just enough for quick retreat to a known and readily available exit. They should also learn that the heat-resistant properties of the garment are meant to allow them to escape from a dangerous situation, not to march into one.

This misconception leads to trouble. The protective clothing and equipment allow firefighters to get into places they should stay out of, and the senses that nature gave them to detect danger are dulled by their equipment. They can't see, they can't smell, they can't feel external temperature changes, and their hearing is impaired. These are hardly advantages to persons in a hazardous environment—and, so equipped, they can venture unsuspectingly into situations of high hazard.

Records in large fire departments show more injuries today than in the era before breathing apparatus and modern protective clothing were used. Yet the firefighters then were just as effective, because they used more caution and somewhat different techniques. In fact, a group of well-trained firefighters in business suits can do an effective job less dangerously than a poorly trained group in state-of-the-art protective equipment.

Although the need for a completely incombustible garment is rare, there have been a sufficient number of serious burn cases to warrant seeking a fire-resistive material, especially if it presents no great disadvantages. There have been cases where the firefighter's garment was so well insulated that he did not discover that its combustible outer shell had ignited, until it was well involved with flame.

Misunderstanding of the properties of aluminized garments can cause trouble. A "proximity" suit is meant to protect by the reflection of radiant heat and, as the name implies, to allow the wearer to approach a fire closely; it is not heavily insulated and should not be worn in flame itself. An "entry" suit is quite different: it is heavily insulated and thus offers much more protection.

Any fire-resistive suit may heat up suddenly, however, and, even though it won't burn, transmit heat to the wearer and burn him unless he can escape from the suit quickly. Safe escape from a heated suit is not possible in the fire zone and is not quickly accomplished even if the wearer is able to get to a safe location. Cooling with water may be the best remedy. Firefighters have been caught by surprise by this sudden heating.

Oxygen breathing apparatus should not be worn under a hooded garment. Excess oxygen may escape through the exhalation valve of the facepiece and collect under the hood, rendering the inner clothing highly susceptible to instant ignition. Air is all right.

IMPORTANCE OF VISIBILITY

Many firefighters have been hurt and several killed because they weren't seen. Some were knocked off roof tops or ladders; some were struck by automobiles. In darkness, a firefighter dressed in black is almost invisible. The only reason I can see for firefighters wearing black is the tyranny of tradition in the fire service. Years ago, all waterproof coats were made of rubber, and rubber was available in black only. Nowadays, all kinds of material and colors are available for firefighters' garments, yet we find that some men are still clad in black. Black is not only the least visible color in the dark, but it also absorbs the most radiant heat.

Most fire departments now use coats which have stripes or borders of reflective material that show up brilliantly when struck by a beam of light at night. It should be noted that this material is reflective, not luminous; it will not glow in darkness. It has to be struck by a light beam at a certain angle in order to shine.

PROTECTION OF THE HEAD AND THE EXTREMITIES

Head protection is available in the form of several styles of helmets, made of a variety of materials. All of them provide protection against impact but in different ways. One uses the natural resiliency of leather; another depends upon padding; a third style employs a crown suspension of fabric webbing. Helmet chin straps have been the subject of much debate. Proponents quote cases of helmets which stayed on the wearers' heads during falls from heights, or off moving vehicles. Opponents cite neck injuries caused by a helmet catching on an unseen wire or other obstruction. Perhaps a quick-release chin strap is the answer.

Hand cuts or burns are a common type of injury. Gloves can eliminate or reduce many of them. When the New York City Fire Department made the wearing of gloves mandatory, the number of hand injuries decreased by several hundred annually.

Boots should have punctureproof soles, because nail punctures of the foot are a frequent hazard.

ELECTRICAL HAZARDS

Electricity presents a grave hazard to crews on the fireground. While I have not been able to discover a single case of a firefighter being electrocuted by current conducted through a hose stream, I do know of four deaths brought on by ladders in contact with charged wires. In one of these, the man was on an aerial ladder and came in contact with the wire. In the others, the victim was on the ground. One firefighter had a foot on the running board of a metal aerial truck and the other on the ground when the ladder touched a high-voltage line. In both of the other cases, a ground ladder hit a wire while men were moving the ladder. In each of these accidents, one of the four men at the base of the ladder was killed and the other three not injured.

Electric current is constantly seeking to return to earth and will, therefore, take the easiest path to ground. If that path happens to run most conveniently through a human body, electrocution is the result. The bird on the wire is safe because it does not provide a path to ground. The firefighter on a metal ladder is in a similar position as long as the ladder is clearly a better electrical path than his body; however, if at a junction of ladder sections, or wherever there may be a path not as direct as the firefighter provides, he could become the primary path; this is especially true where he touches a wire while on the ladder, or if he provides the path from the base of the ladder to the ground.

Firemen's rubber boots have some insulating quality because they are made of rubber, but are not reliable insulators because carbon black (a conductor) is used in the rubber to give it strength. Thus the insulating value is greatly decreased. Furthermore, firefighters' boots pick up much metal in the form of small nails, especially the boots of ladder company members who do the overhauling. When I was a fireman, I would periodically use pliers to remove this metal from the soles of my boots. Many times I would remove 30 to 40 nails from each boot; this amount of metal in the sole could make it conductive.

HANDLING LIVE WIRES

Firefighters should not attempt to cut live wires except under extreme emergencies and then only upon wearing utility lineman's

Any Failure of a Structure is a collapse.

rubber gloves. Many fire companies provide such gloves, but not all of them are well maintained to assure complete safety; they should be well cared for and given periodic dielectric tests.

When a firefighter must pull a fuse or an electric switch, he should use a dry nonconducting object rather than bare hands, especially if he is wet or standing in a wet spot. When he touches electric equipment, it is advisable that he touch first with the back of the hand so that if a shock contracts the muscle of his hand, it will not cause it to clutch the charged object.

Whenever a firefighter descends into a sewer, manhole, pit, well, or any other underground recess, it is wise to wear self-contained breathing apparatus. Several firefighters have died from inhaling toxic gases or from lack of oxygen in such circumstances, even in relatively shallow (less than eight feet deep) holes.

SECONDARY INJURIES

Another aspect of safety which is difficult to anticipate, but which takes a surprisingly heavy toll, is secondary injury at the fire scene. By this I mean an injury which is not caused by the fire. For instance, a firefighter ventilated the rear of a store and then climbed over a board fence to return to the front by way of the store next door. The store next door happened to be a restaurant, in which some fat had just been boiled and set out in the yard in an uncovered 55-gallon drum; the fireman dropped into it and was severely burned. In another instance, a firefighter, walking through a smoke-filled factory, stepped into a vat of caustic and was killed. In another case, a fire officer, walking through an alley at night, stepped into a pit of hot water and was scalded to death. There have been cases of firefighters being killed by stepping into holes. I almost stepped into a well in an abandoned brewery. The fire was minor; the property was virtually worthless. As I walked through the dark, my flashlight suddenly disclosed an unguarded opening in the floor about five feet in diameter. The bottom was 150 feet below, and one more step would have taken me there.

In cases like this, the flashlight is of great value, but where smoke renders the flashlight useless, the firefighter can protect himself by pushing a tool in front of him, along the floor, as he walks. If the tool suddenly drops, a hole is indicated. Another precaution is to walk "boxer style" when a hole or weakness is suspected. In this fashion, one foot is put forward as a probe while the weight rests on the other.

Stepping off a ladder under poor light conditions requires caution: don't let go of the ladder until footing is assured. Firefighters have been killed by stepping off a ladder into a window which served an open shaft. (That is why shaft windows have to be barricaded and marked in New York City.) Others have been hurt by stepping into stairways or over extremely high roof parapets. One of the oddest accidents I ever saw happened when a lieutenant stepped off a ladder on to what he thought was a roof. It turned out to be an alleyway between two buildings which had a common front that masked the alleyway. At a recent Florida fire, a mask-clad firefighter stepped off a ladder into heavy smoke only to find that the ladder had not been placed over the roof. Fortunately, he only fell one story and his injuries were not serious.

Good illumination of the fire scene after dark can eliminate many injuries. It should be provided as soon as possible, but with today's personnel shortage, it is often left until after the fire has been knocked down. Even then, it is a case of better late than never, but the earlier lighting is provided, the fewer will be the injuries. Every firefighter should carry a reliable flashlight, even though he or she will not always have a hand free to use it. Officers should keep a hand free for illuminating the area where their crews are working. Chief officers should see that large-scale illumination is provided promptly.

GETTING LOST

Mention is often made of using a hose line as a guide to an exit if retreat without visibility is necessary. This idea is good, but what of the times that firefighters are working at duties such as search and ventilation in smoke-obscured areas without a hose line? In that case, they should make their own "search size-up" before entering. It should include:

1. An estimate of the floor layout, with the location of windows and exits (A quick look from the outside or at the floor below, if possible, could help.)
2. Distance to and direction of windows and alternate exits
3. Location of fire in relation to the search area
4. Any likely hazards, i.e., a hole in the floor, unprotected floor openings, floor collapse potential, fire extension, dangerous contents, and so on

The firefighter's direction of travel should be systematic, such as moving to the left, with the left hand on the wall if the area is large. (There is, however, the true story of the firefighter who did just that and, when the smoke cleared, found that he had been walking around a huge circular column for ten minutes.)

Some firefighters carry a personal rope about 40 feet long, which can be tied near the window or door upon entering and serve as a guide for safe departure; furthermore, if its owner needs help, it will serve as a guide for rescuers. Also, it can be used for sliding to safety, either with the escape harness worn in New York City, or without it by the "ironworker's slide," which needs no equipment other than the rope.

Sometimes, when lost, a firefighter can use his senses in various ways to reorient himself and get to safety. Careful listening may reveal the sound of an engine pumping and thus point to the street. Feeling the cracks between floorboards will lead to a side wall if these are followed carefully. Similarly, he could follow one of the seams in a concrete floor; if smoke is not too thick, a strong flashlight might reveal the floor to permit this procedure. Once a firefighter has found a wall, following it should lead to an opening eventually.

CRITICAL INCIDENT STRESS

In what might be considered "psychological safety" some fire departments are making an effort to recognize and mitigate adverse emotional reactions of personnel to stressful situations. The subject is being taught at the National Fire Academy by Deputy Chief Charles Fisher of the Kansas City, Missouri, Fire Department. Chief Fisher has kindly submitted the information that follows:

> ### Critical Incident Stress
>
> A fire service career has always been a stressful occupation. People don't normally call on us when they're having fun; it's when there is serious trouble that we are called to respond. How many times in your career have you been placed in that most difficult position of trying to save a life? When we are successful, the feeling is indescribable, and no amount of compensation could equal that sense of accomplishment we feel when our professional effort has been the difference between life and death for the citizens we serve.
>
> Unfortunately, we can't always be successful. Despite tremendous effort, we are too often confronted with death in too many different forms—the incinerated fire victim, the infant or young child mangled in an automobile, the tragic loss of a young fellow firefighter. These types of events can have an especially profound effect on many members of your department, and sometimes on the entire agency.

> The magnitude of some events is so great as to touch every member of the fire service. The fire and roof collapse at an auto dealership in Hackensack, New Jersey, which took five firefighters' lives or the ammonium nitrate blast in Kansas City, Missouri, which killed six firefighters are vivid examples of such incidents. The normal peer support processes we routinely use to help one another through stressful events is overwhelmed by these catastrophes and needs a "jump start" to get it back on line. The procedure we use to provide that start is Critical Incident Stress Debriefing.
>
> The CISD process is used solely to regenerate the normal support process so important to us in the fire service. It is not a "quick-fix" or a psychological hocus-pocus sort of affair where some bunch of shrinks comes in to practice psychoanalytic techniques on your personnel. It is set up as a support group discussion, very confidential in nature, utilizing a specially trained mental health professional to work with peer support personnel from the emergency services field. Its main goal is to lessen the long-term psychological impact of the event and to accelerate the recovery process for personnel experiencing what are in essence the normal reactions to very abnormal events.
>
> A critical element from my perspective as a fire command officer is that the process must be peer-driven, rather than a function of the mental health professionals. Outside personnel entering the fire service group, especially in the wake of a major event, will lead a firefighter to clam up as if infected with a severe case of lockjaw. The careful selection of team members and their early integration into your departmental structure is critical to the eventual success of your CISD program.

How can injuries be prevented? There should be a continuing educational effort to make all officers and firefighters safety-conscious. Coupled with this effort, there should be a training program that teaches the safest methods of accomplishing prescribed tasks. An analysis of previous injuries should disclose a basis for both.

In industrial accident analysis, a distinction is made as to whether the accident was caused by an unsafe act or an unsafe condition. In firefighting, however, the unsafe conditions in the work environment are fundamental to the occupation and are not subject to elimination by administrative action as they would be in industry. Risk acceptance is essential to the task and sets this type of work apart

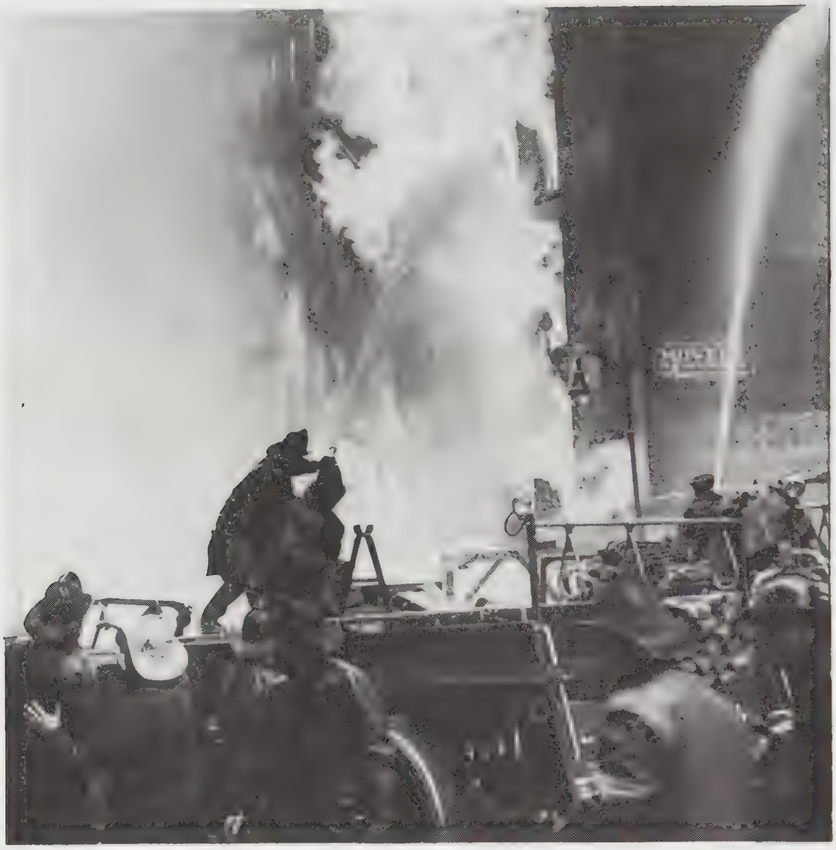


Figure 8.13. *Stream penetration was sacrificed for safety when turret pipes were positioned at the corner of this building (the safest place in the event of collapse). The front wall collapsed about five minutes after this picture was taken.*

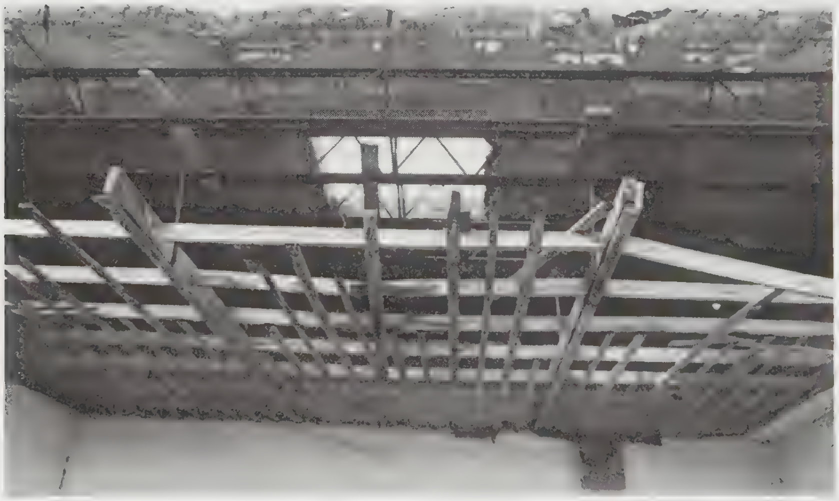


Figure 8.14. *Partial demolition exposes the hazards of this hanging ceiling in a store. It is suspended from the roof joists by metal rods, which are attached to wood two-by-fours at the top and to two-by-sixes at the bottom. If either burns through, the ceiling will drop.*

from most other occupations. Nevertheless, an awareness of how fire accidents occur, and how to guard against them, should be instilled in all personnel by a systematic training program.

The difference between aggressive firefighting and unnecessary risk taking should be clearly delineated and objectives set for the occasion. Dr. Harry Carter, a veteran fire officer and author, says that the life hazard to the occupants should determine the firefighting risks acceptable.

Firefighters must be taught to identify unsafe conditions and avoid unsafe acts. Protective equipment is not meant to take the place of knowledge. Technology is not a satisfactory substitute for clear thinking.

9

The Fire Building—Hindrance and Help

IF A FIRE officer is to be effective in combating fires in buildings, he or she should be familiar with the features of buildings which are critical during firefighting operations. These considerations should be approached from two standpoints: *(1)* fire spread and *(2)* structural failure or collapse.

Structural features can affect fire spread adversely or favorably. Some buildings offer no protection and merely provide fuel sources and avenues of fire travel. Other structures are made to resist fire spread by being built of incombustible materials and with structural safeguards that limit the extent of a fire.

The most common means of fire travel are by way of vertical arteries such as open stairways, light and air shafts, dumbwaiter shafts, and utility shafts (in some buildings, electric conduits, water pipes, and telephone wires are carried upward in a utility shaft measuring about four square feet). Elevator shafts can carry lethal amounts of smoke but are seldom a means of fire travel.

Other vertical arteries are ducts for ventilation of bathrooms and kitchens in multi-storied buildings, and air-conditioning ducts in some buildings where central air conditioning involves more than one story.

Another type of vertical opening—but an uncommon one—is the belt opening in a floor where factory machinery is driven by a belt attached to a motor on either the floor above or below. Also, in some industrial occupancies there will be chutes or conveyors going from one floor to another. In some buildings, spaces in walls are vertical channels. The vertical arteries do not have to be combustible to carry fire to upper floors; fire can travel upward rapidly through an incombustible shaft. In experiments conducted at the Florida State Fire College, a fire which was started at the bottom of an incombustible shaft ignited wood stored on the top floor of a three-story building one minute after ignition. The wood on the third floor ignited long before similar wood projecting into the shaft on the second floor, proving that the heat rose rapidly until it reached the covering on the top of the shaft and then banked down.

VERTICAL SPREAD OF HEAT AND SMOKE

Some hotel fires which took a large toll of lives serve as illustrations of vertical spread of heat and smoke. In the Wynecoff Hotel in Atlanta, Georgia, the stairway served as a flue. In the Hotel Roosevelt in Jacksonville, Florida, the smoke and heat rose through utility shafts and ventilating ducts. Both of these buildings were of so-called "fire-resistive" construction. The principal structural components won't burn, but smoke and heat can travel to many parts of the building and kill people. (Both of these buildings suffered little structural damage and are still in use.)

In the type of building known as "balloon-frame" construction, fire can travel rapidly upward in the space between the outer wall and inner wall, unless fire stops (usually horizontal two-by-fours) have been installed between the studs (vertical two-by-fours) of the wall. This is a common means of fire travel in wood-frame buildings constructed prior to 1940 or thereabouts (Figure 9.1). Since most of these buildings are dwellings with an attic, it is not uncommon to find that fire has extended from the basement to the attic even before the fire department arrived.

When heat travels upward between walls, sometimes—but not always—it will indicate its passage by blistering or discoloring the paint on the inside walls. Such indication warrants opening the wall for examination, but, more than that, it calls for prompt examination of the topmost part of the building (attic or cockloft).

Light and air shafts are a double threat. When fire enters such a shaft from a window on the fire floor, there is immediate danger of fire entering all windows on the same and higher floors. Often there are two buildings served by the shaft, and fire can enter windows on several floors in both buildings. I have seen cases where this con-

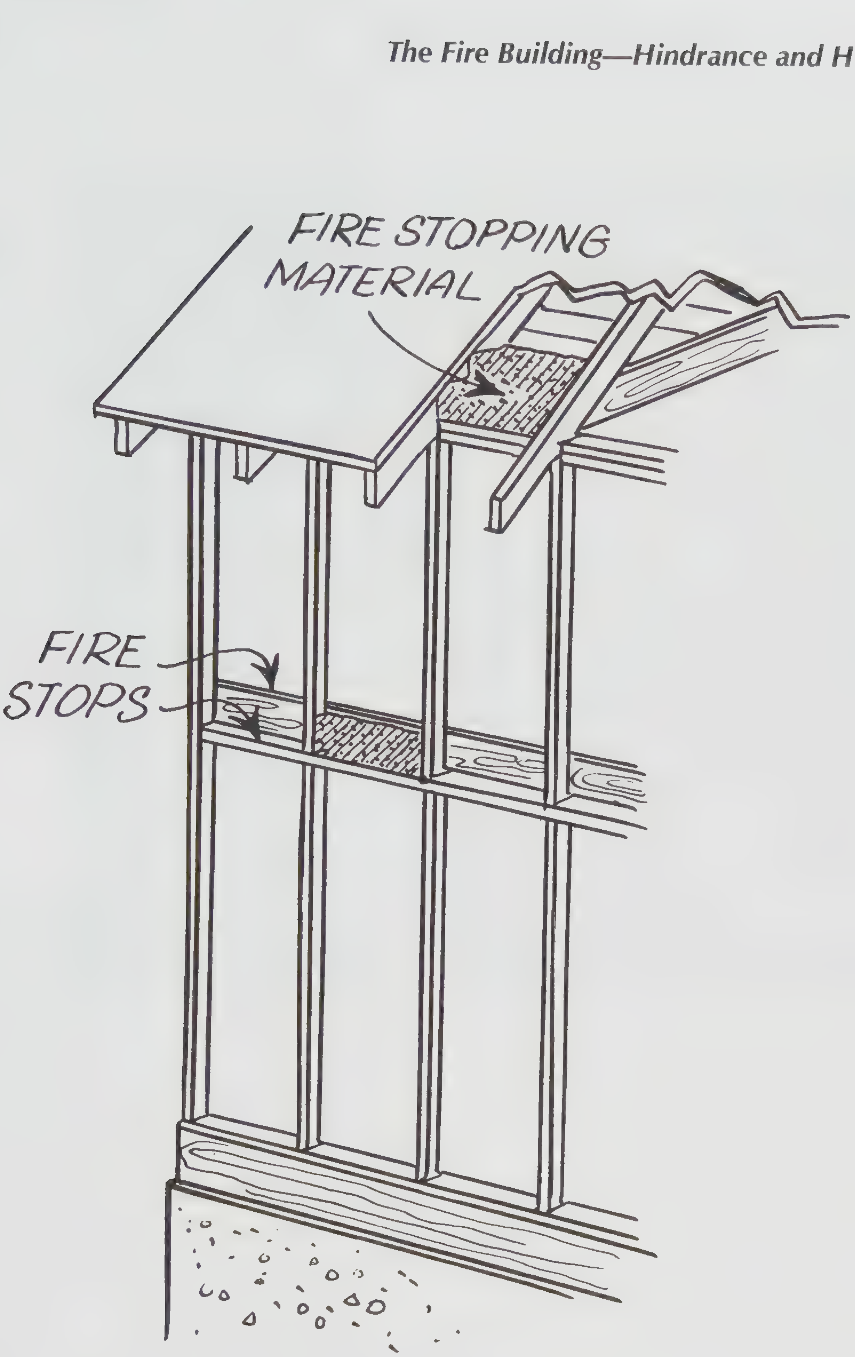


Figure 9.1. Balloon-frame construction was used in the building boom of the early twentieth century, particularly for dwellings. No fire-stopping was used in the flue-like spaces between studs, and fire can travel unchecked from cellar to attic. In more recent construction, fire-stopping was introduced to hinder fire spread both horizontally and vertically, as indicated above.

struction meant fire—-and plenty of it—on six stories in each of two tenements. There is one consolation in this type of fire: the thermal updraft in the open shaft is so great that the stairways remain free of smoke and heat because they serve as fresh air intakes for the fire, while the shaft serves as the exhaust route.

Mushrooming of Fire

In many cases, vertical extension of fire will become horizontal extension as well, unless steps are taken to prevent horizontal spread. Heat will travel upward rapidly until it meets an obstruction; then it will spread laterally. For this reason, we find that in multi-storied buildings, the top story is the most vulnerable. The condition known as mushrooming occurs when the smoke and heat travel upward to the top floor and then, unable to escape or travel farther upward, spread horizontally (and in some extreme cases, bank down too).

One way to prevent mushrooming is to ventilate at the top of the vertical arteries. Removing their coverings permits the heat to escape to the atmosphere. Nevertheless, hose lines should be taken to the places most vulnerable, such as the top floor and the floor above the fire, if conditions indicate possible extension. Whenever fire has entered a stairway or similar covered shaft, it should be assumed that it will mushroom on the top floor.

Downward Fire Travel

There are two types of vertical channels that will allow fire to drop down. Such spread doesn't happen often and therefore can catch an officer off guard. A certain type of steel skeleton construction, used mostly in apartment houses, has vertical steel members which are H-shaped, and which extend for as much as 30 feet without any obstruction between the top and bottom of the "H." Sparks and embers can drop through these channels until they meet an obstruction (Figure 9.2). I once saw fire drop two floors through an "H" column and ignite the baseboard in an apartment wall. Another type of vertical fire drop occurs in the recessed channels of sliding doors in older buildings. The presence of these construction features demands an examination below the fire as well as above.

Although vertical fire spread is more likely, horizontal spread is quite common. It can be expected where there are no dividing walls, and it can also occur where such walls exist but are not complete enough to prevent the spread of fire from one side to the other.

Such fire travel can be through a wall opening or over the top of the wall. Many times a fire-resistive wall is pierced to permit pipes or wires to be carried horizontally. Hanging ceilings are a common means of horizontal fire travel over a wall. I recently saw a new school building with fire walls and fire doors in those walls, but with an undivided hanging ceiling space in the corridor which went right over the fire doors.

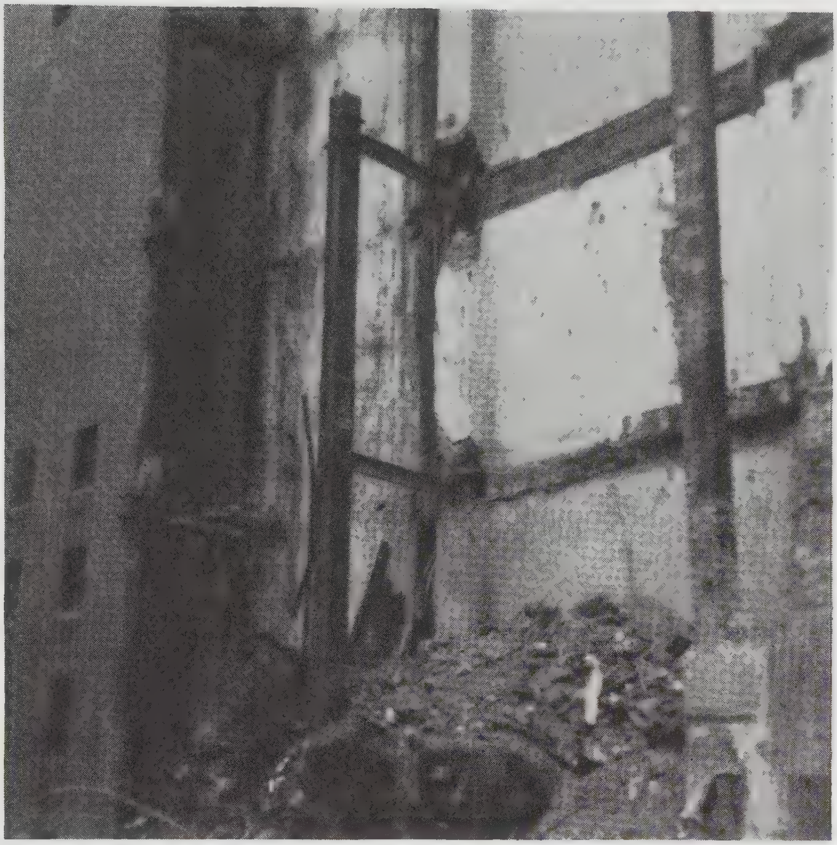


Figure 9.2. This open-channel structural steel column (center) *that extends for as much as 30 feet permits fire to travel past more than one floor and also allows embers to drop and start fires below.*

Air-conditioning or hot air heating ducts sometimes run through fire-resistive walls and can carry heat, smoke, and gases from one side of the wall to portions of the building on the other side. This problem is on the increase. Many building codes permit air-conditioning ducts to connect all sections of a building. Deaths from toxic fire gases conveyed to a point remote from the fire by these ducts have been reported. At a test fire in New York City, heat traveled through a duct, came out an opening, and ignited paper on top of a desk.

The cockloft, or space between the bottom of the roof and the ceiling of the top floor, is one of the worst horizontal means of fire travel (Figure 9.3). It is hard to get at and affords a large and ready avenue, usually lined with combustible material, and, most of the time, dust to feed the fire. For those reasons, cockloft fires are among the most destructive.

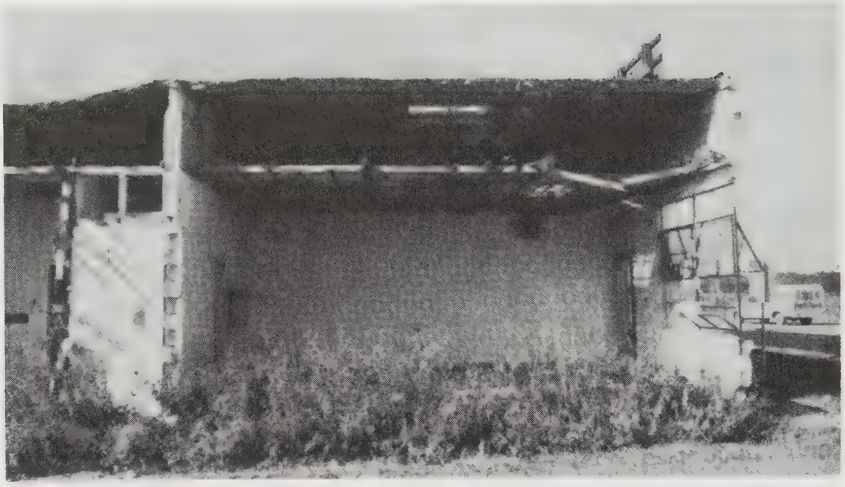


Figure 9.3. *Fire in a cockloft (the space between the under side of a roof and the ceiling of a top floor) can be difficult to fight. Cocklofts are usually constructed with combustible material and frequently extend undivided over a row of stores or dwellings.*

Extension via Beam Ends

It is rare that heat from a fire will be conducted by an incombustible wall, but it can happen. More common, but still unusual, is fire travel from the beam ends of one building through a party wall into the beam ends of an adjacent building. This type of fire travel is insidious, in that a search prior to its happening will not disclose it and thus gives a false sense of safety. The type of building where this extension happens is usually the old mercantile built prior to 1920. When a fire is well advanced in such a building, it is well to make repeated examinations in adjoining buildings for fire extension. A single examination is not enough. The search should be repeated as long as the threat exists. There have been cases where an examination showed no sign of fire extension, but the fire later took possession of the entire building next door and was discovered only when it broke out the windows.

Another means of horizontal travel is by way of the cornice along the front of a building. Sometimes the same cornice serves several buildings without being fire-stopped. In some cases, the fire wall extends above the roof, but the cornice is not stopped and fire can travel past the wall.

Parapets are vertical extensions which carry the walls of a building above the roof to keep fire which is burning the roof of one building from igniting the roof of an adjoining building. The effectiveness of parapets as fire stops usually varies with their height. A

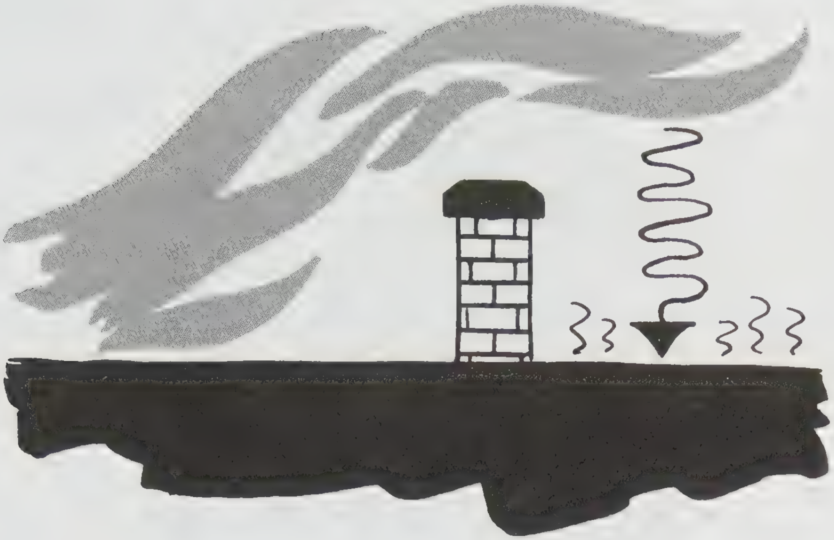


Figure 9.4. *Flames, particularly wind-driven, can travel over a roof parapet and radiate heat that can ignite an adjoining roof.*

parapet less than two feet high is not much of a guarantee when flames are high and close, especially if the wind is blowing toward the exposed building (Figure 9.4). NFPA standards suggest a parapet height of at least three feet to protect a combustible roof, but even with a parapet that high, ignition is possible and should be guarded against. The wind can bend flame over the parapet, and heat radiating downward from the flame can ignite a combustible surface.

Modern cement block construction of stores in a row, each separated by cement block walls from those on either side, can be deceiving. Sometimes a metal deck roof that rests on bar joists is carried over the whole row, unfortunately with a space between the top of the cement block walls and the under side of the roof. This arrangement is hardly a cockloft, but is a void large enough to permit heat and smoke to travel through the whole row of stores. Even though the roof, bar joists, and walls are incombustible, the heat can ignite combustible ceiling tiles and bank down into each store to ignite stock. In this type of construction, the most vulnerable points include not only the stores adjacent to the one on fire, but also the end stores, especially the one on the downwind side (Figure 9.5). If a glance at the roof shows no parapets, then either this type of construction or a common cockloft is likely.

The opposite of the common cockloft is the common cellar, sometimes found under a row of stores. Each store has its own share of the cellar, but it is separated from the others by combustible partitions or, sometimes, just wire fences. Each store will have its own interior

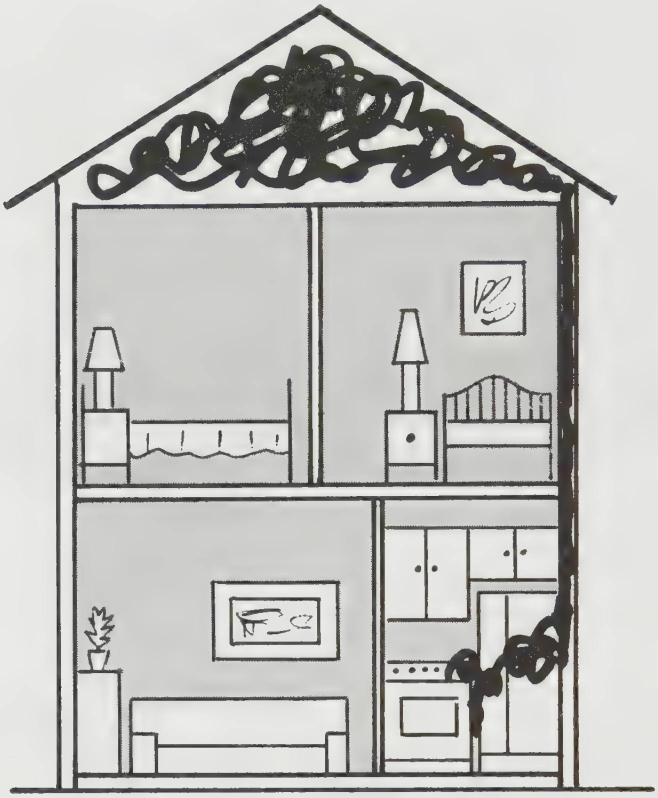


Figure 9.5. Distant flashover: Fire can travel upward through walls and flash over at a distant point without flashover occurring in the room of the fire's origin.

cellar stairs (and sometimes a stair to the outside). Fire can travel throughout the cellar and climb into any of the stores as well by way of the interior stairs, through the floor, or up the walls.

Fire travel by conduction is not frequent but can happen when a pipe passing through a floor or wall is heated sufficiently to conduct heat along its length to where it is in contact with easily ignited material on the other side of the wall from the fire (Figure 9.6).

CLUES GIVEN BY A BUILDING'S AGE

The age of a building will give several clues as to how it may behave when subjected to fire. And the face of the building—unless modernized—will give a clue to its age. In this connection, if there is any doubt, it is well to look at the sides or rear of the structure, because modernization does not usually involve these less visible surfaces. Sometimes a very modern front is just a facade hiding a century-old building.

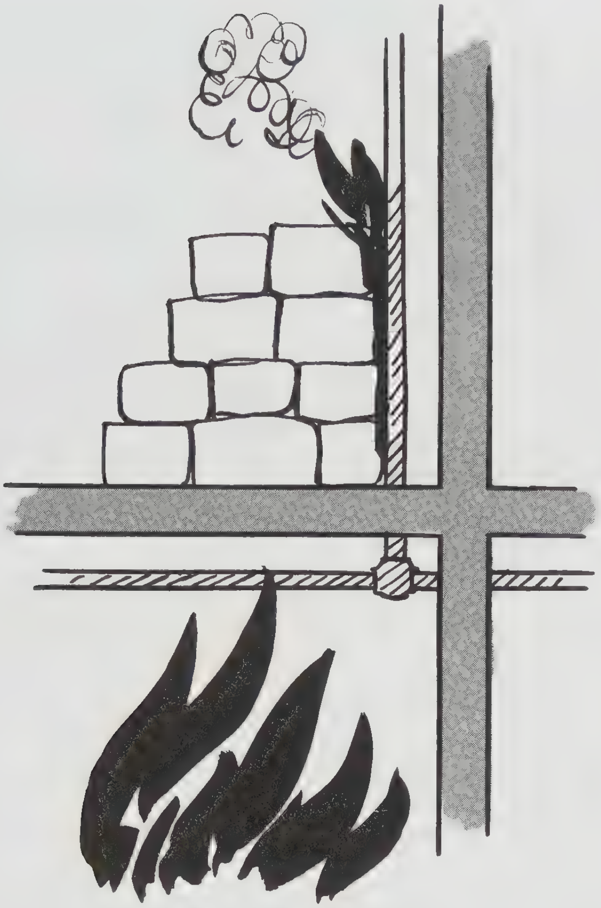


Figure 9.6. Fire can travel by conduction. In this case, fire on the floor below heated a soil pipe, which conducted heat to material on the floor above.

Building age is a fairly reliable indication of construction features, and certain construction features indicate the age. Brick buildings erected in the early 1900s and before have lime mortar connecting the bricks; those erected in more recent times use portland cement as the bond. The latter gives a stronger, better-bonded wall, less prone to collapse. It can be identified by the window lintels. When lime mortar was used, the lintels above the windows were either bricks in a keystone arch, or one piece of solid stone. The advent of portland cement permitted the use of steel lintels, which don't show and give a clean straight line of brick across the tops of the windows. These signs not only indicate the age of the building but offer clues to its construction. It is almost certain that the buildings with keystone arches and stone lintels are not resistive to fire. They probably have wood floors on wood joists and open combustible stairways.

Based on personal observation, I venture the opinion that more

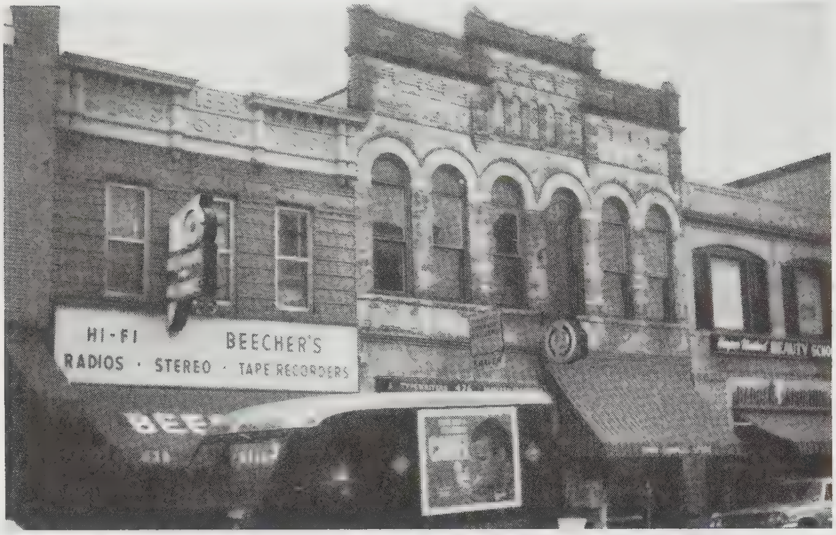


Figure 9.7. *Mercantile buildings constructed in the boom following the Civil War are still in use, particularly in the Midwest. Subjected to multiple alterations and re-alterations, they are now worse instead of better, from the firefighting viewpoint. Keystone arches and stone lintels (in the buildings shown) usually indicate that the building is non-fire-resistive.*

than half the mercantile buildings in the United States still fall into this category; there was evidently a great boom in this country following the end of the Civil War. In the period from 1870 to 1890, a great many mercantile buildings were erected throughout the Midwest and the West. A lot of industrial buildings were built then, too, but they grew obsolete and were replaced, while the mercantiles merely underwent alteration. The alteration of these structures made them worse instead of better from the firefighting standpoint. Usually, alterations weaken rather than strengthen a building. Beams are cut to allow the passage of new pipes. Conduits and ducts are carried through floors. Floors are subjected to heavier loads than they were built to withstand, and concealed spaces are created.

In that respect, the most common are dropped ceilings and elevated floors; some buildings even possess the unhappy combination of both. Fires in these spaces are most difficult to combat. Sometimes, when the ceiling is pulled down, firefighters do not suspect that above the space exposed is another void created by the presence of an old ceiling or a new floor. These spaces can also harbor a collection of fire gases, which may explode when conditions are just right.

Some ancient structures are bolstered by tie rods which hold opposite walls; this process is known as "anchoring" a building. The presence of anchors is usually indicated by ornamental stars on the outside of the walls at the ends of the tie rods; the presence of these stars is a warning signal to firefighters to be careful.

Ⓣ Bow S
Peak
Parallel — most Dangerous

STRUCTURAL FAILURE

Probably the greatest hazard in firefighting is the collapse of buildings. It is likely that most of the on-site deaths of firefighters occur from this cause. Buildings can collapse quickly and with little warning. Not only is collapse a safety hazard, but it is also an extension hazard. The sudden release of energy when a large structure collapses can ignite nearby properties that were not previously endangered. Therefore, collapse probability and effect should be studied.

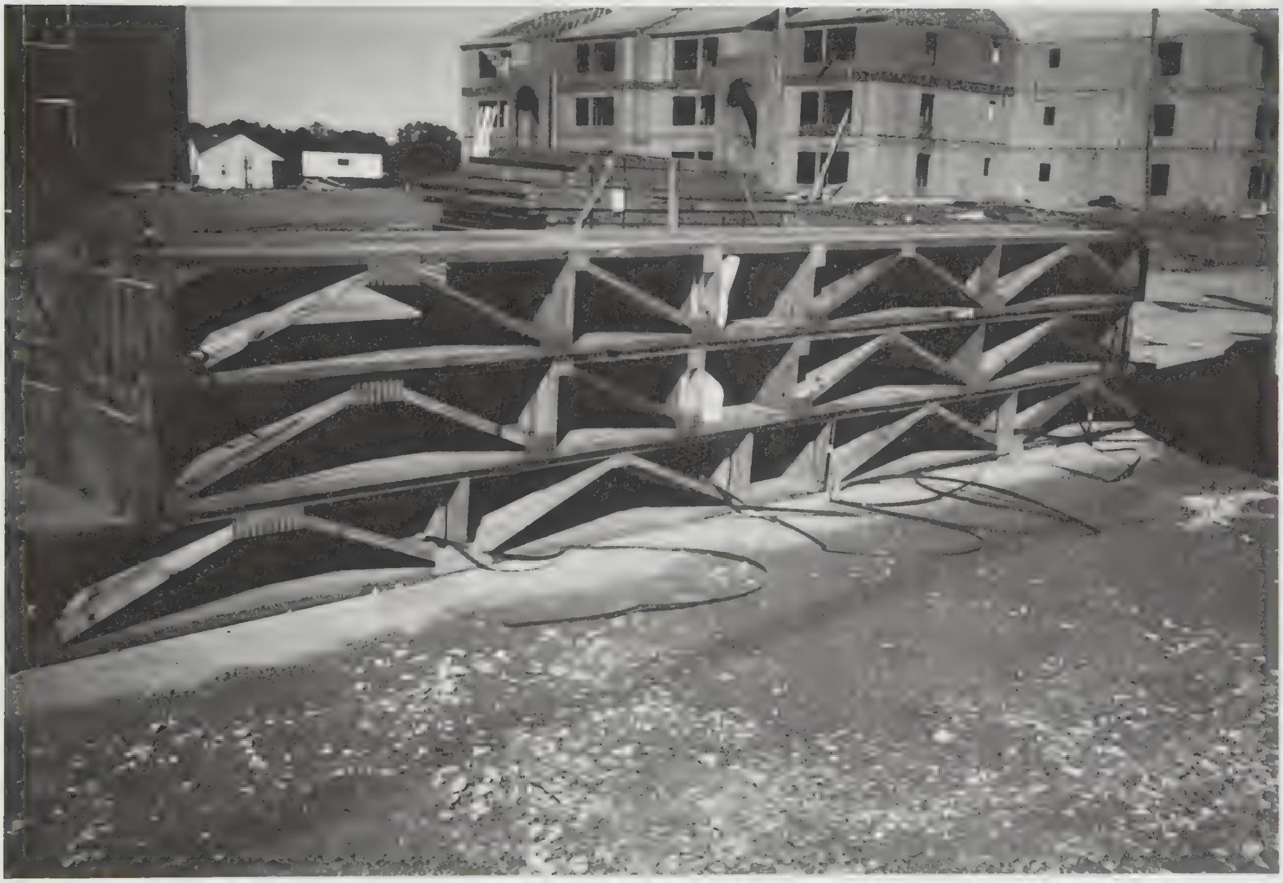


Figure 9.8. *Wood floor trusses became popular in the 1980s for use in multiple dwellings and other occupancies where local codes allow wood structural members. Those piled in the foreground are three high and several thick; they are usually made of two-by-fours. In the background of this photograph are garden apartments, where many such trusses have been installed, along with wood roof trusses such as those piled in the middle ground.*

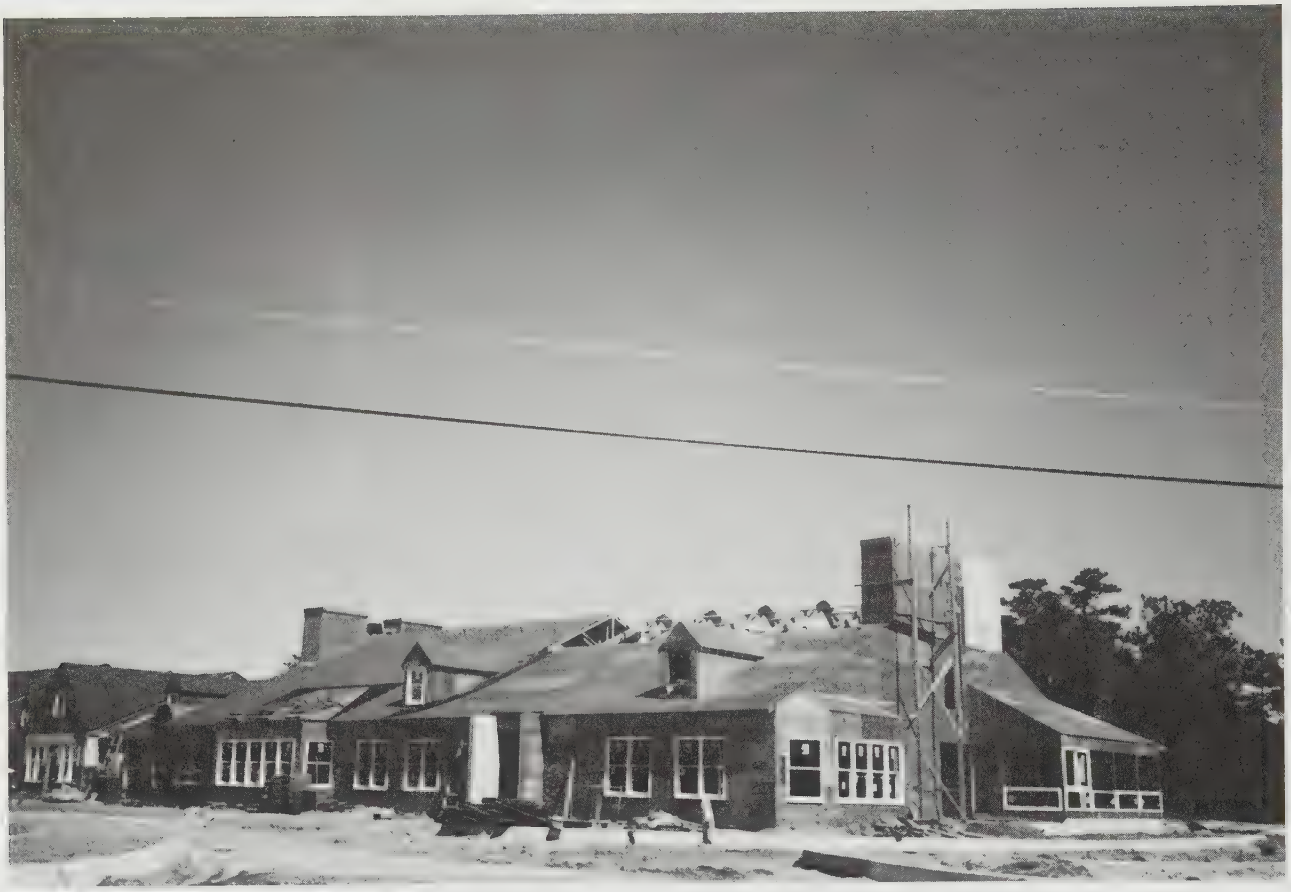


Figure 9.9. *Built to burn and collapse early, this suburban office complex has plywood walls and roof. The roof is supported by wood trusses. Even without truss failure, there is enough space between trusses for a firefighter to fall through the plywood if it were to become fire-weakened.*

There are no sure indications of when a building will collapse other than a noticeable bulge in a brick wall—a sign that should be respected. When it appears, the assumption should be that a major collapse is due soon at that point; however, this statement does not mean that a bulge precedes every brick wall collapse. Far from it—many brick walls have collapsed without such a warning. Cracks are no positive indication. They may even have been present before the fire started, but a large crack with smoke pushing through it is worthy of respect.

Wall failures are hard to predict and so is their behavior. It is often said that a brick wall will fall within one-third of its height (the ground area covered by the falling bricks, measured from the base of the wall). Yet during one of our fire tests at Waukesha, Wisconsin, the four walls of a three-story brick school building fell in different

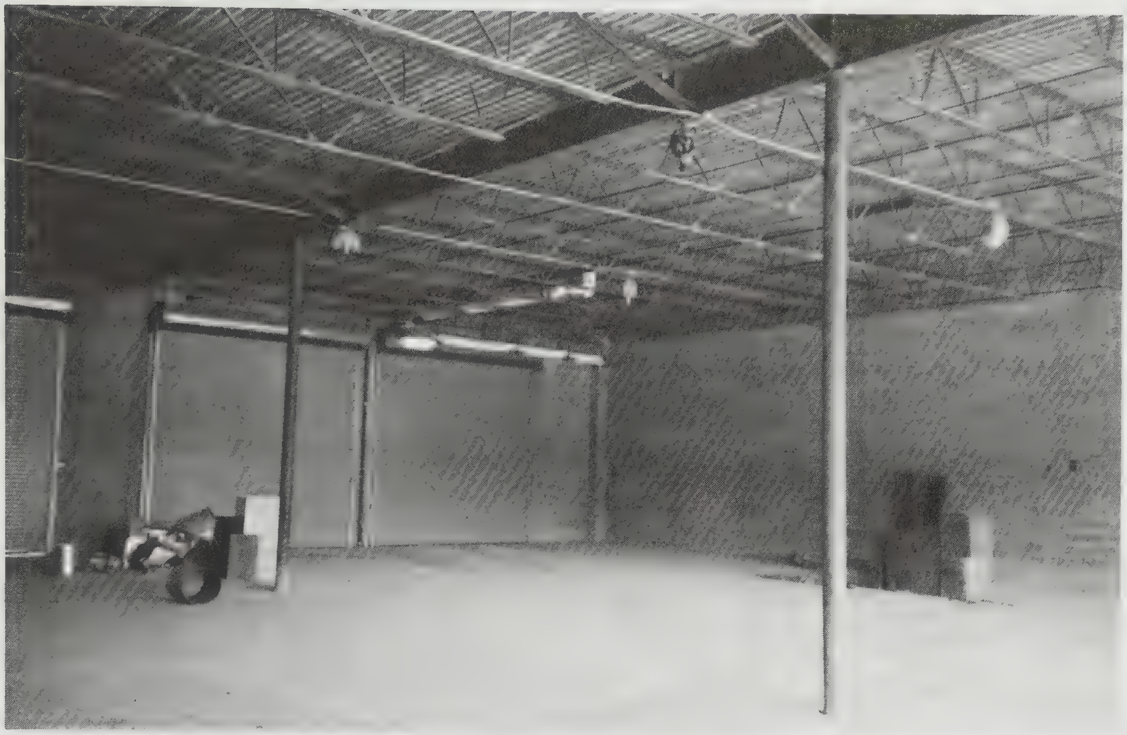


Figure 9.10. *A truss roof is not necessary for a collapse in a one-story building, nor are any wood structural members. The important features of non-combustible buildings are shown here. A metal roof deck is supported by steel bar joists resting on concrete block walls and a steel girder, which is held up by cast iron columns; a heavy fire load in such a building could cause failure of these structural members. The heated metal will not only lose strength but will elongate and warp, possibly pushing walls out.*

patterns, ranging from one-third of the height to almost the full height. The walls fell one at a time—south wall, east wall, west wall, north wall, with the first wall falling 45 minutes after the building became fully involved and well after the fire had passed its peak. (No water was being used.) The last wall fell an hour and a half after the first; that was the one which traveled farthest from the base, probably because it had no bond to any other wall. Each wall fell without any pushing by hose streams or any other influence; the fire had been allowed to burn freely.

BUILDING COLLAPSE

Buildings can collapse in what is known as the "pancake" collapse, where a floor lands on the one below and pushes it down on top of the one below that, and so on until all the floors end up like a stack of pancakes (Figure 9.11).

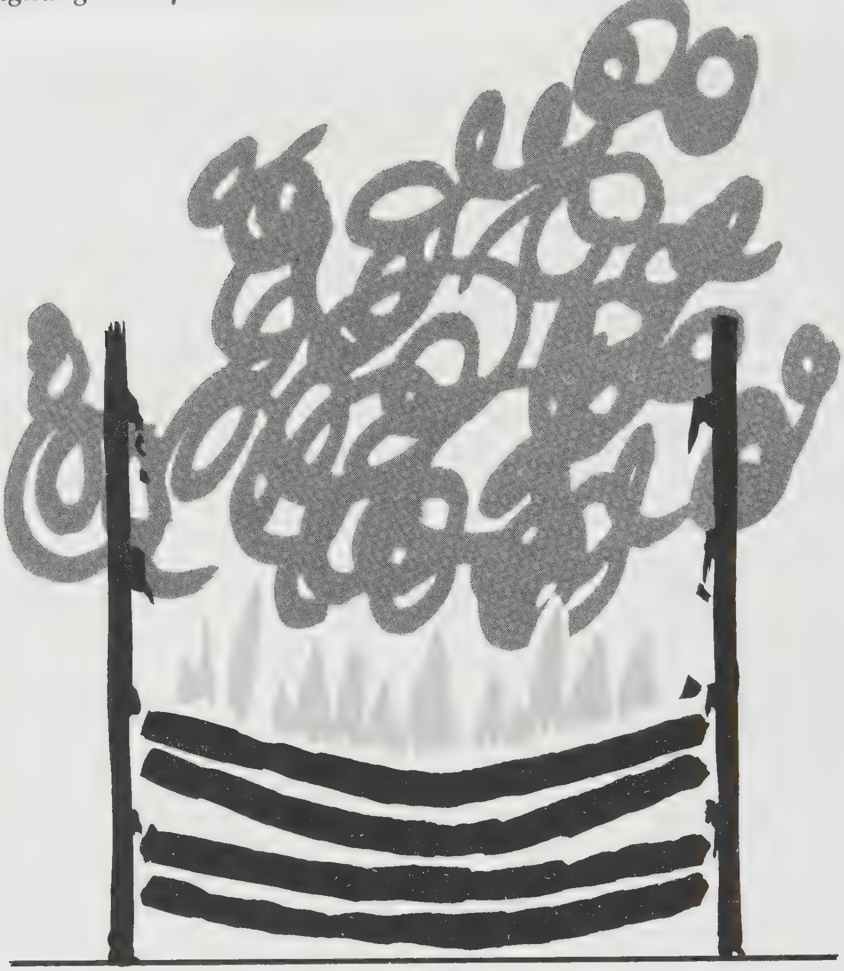


Figure 9.11. In a pancake collapse, one floor of the building lands on the floor below and pushes it down to the floor below that, and so on, until the first floor collapses into the cellar.

Then there is the "lean-to" collapse of a roof, usually in a church or similar large one-story building (Figure 9.12). In this type of collapse, the roof falls in at the middle and leaves a triangular void at each side, where it is possible for people to survive. That is why it is safer near the side than in the center inside such a building.

The type of roof most prone to collapse is the truss. Whether it be of steel or wood, the truss roof will collapse quickly when exposed to the heat of a fire. In fact, I once went to a fire, first due, and the roof had collapsed before our arrival. The early collapse occurs because the truss is made of light structural members, dependent upon each other. When a key member fails, the others dependent on it must go with it, and the effect is like the falling of a "house of cards." It is extremely dangerous to put firefighters on such a roof. Also, when a truss roof falls, it usually pushes out the brick wall where the truss rests. I have seen men severely injured by such a falling wall.

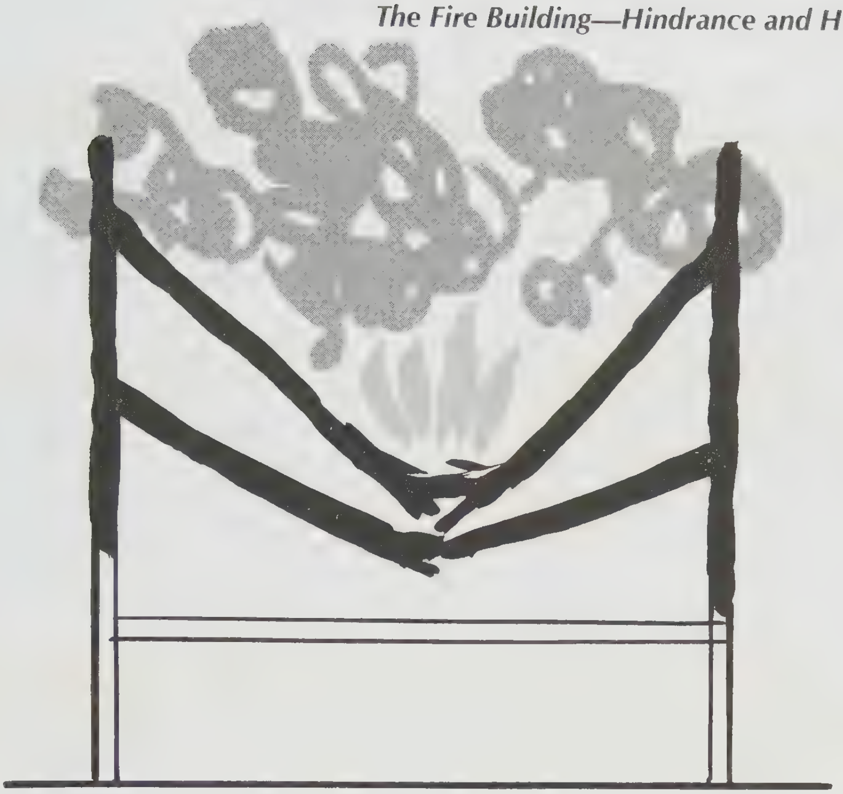


Figure 9.12. *In a lean-to collapse, the roof falls in at the center as though hinged at the walls, which remain standing. Such a collapse usually occurs in a church or similar buildings.*

Figure 9.13. *Truss roofs are commonly found on supermarkets, bowling alleys, and other occupancies where large floor areas uninterrupted by columns are desired. All members of the roof are interdependent, and the failure of one member can cause the collapse of all.*

Truss roofs are commonly found on supermarkets, bowling alleys, armories, gymnasiums, and other structures where it is desirable to have a large floor area uninterrupted by columns (Figure 9.13).

Another type of one-story building that is prone to early collapse is the one with long-span steel girders. The steel expands when heated and pushes the walls out. Steel increases .07 percent of its length for each 100°F rise in temperature. Translated into feet, this means an expansion of .1 of an inch for each foot of length when the temperature rises 1,200°F. This formula would mean a substantial expansion of five inches in a 50-foot span. Furthermore, unprotected steel (steel not insulated with an incombustible covering) will have lost 90 percent of its strength at about 1,400°F, a temperature which is common at the ceiling of a fire area.

Contrary to popular belief, steel, though it is not readily combustible, is not especially fire-resistive. Steel buildings and masonry buildings with unprotected structural steel members are not structurally reliable under heavy fire conditions. Some of the common methods of protecting structural steel are to cover it with gypsum board, or vermiculite plaster on wire lath, or with a sprayed coating. The third has been found missing in places at some recent fires, with serious structural damage resulting.

Cast iron has great compression strength, but little tensile strength. Therefore, it was widely used for columns in buildings erected up until the early 1900s. Its weakness is uneven contraction and possible failure when struck by water.

In the late 1800s, many mercantile buildings were erected with cast-iron fronts. These fronts can collapse in one huge piece. Such fronts are recognizable by their heavy ornamentation and the fact that they have to be painted. (The U.S. Capitol dome is cast iron and is painted a dull white so that it matches the masonry walls.)

Concrete is far more fire-resistive than steel, and the structural stability of reinforced concrete buildings has been excellent—but not perfect—under fire conditions. There have been cases of failure of concrete under heavy fire loads, but it is a rare occurrence. More common, however, is the spalling of concrete, i.e., thin pieces of it dropping, when heated. While this process is not a structural failure, it could injure firefighters.

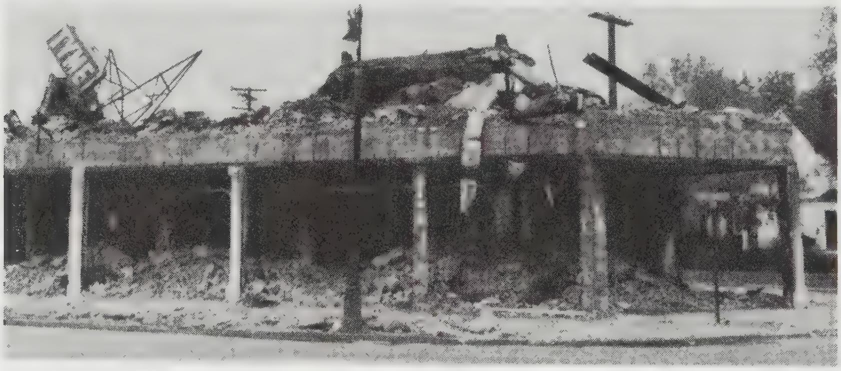


Figure 9.14. *Fire in this reinforced concrete furniture store burned unchecked during civil disturbances. The principal structural members still remain in what was a two-story building.*

MILL CONSTRUCTION

Heavy timber construction, sometimes called mill construction, is more fire-resistive than unprotected steel, because the mass of the structural members and thickness of the floors make for slow burning. Although this type of building is fast disappearing, there are many large ones still in existence, especially in New England, where they were the standard structure for textile mills and leather goods factories. There are many southern textile mills of this type, and concentrations of these buildings are found in parts of New Jersey and New York, with scatterings of them elsewhere. Although large and combustible, they have no concealed spaces and are not prone to collapse.

In addition to those already discussed, the causes of structural collapse are several:

1. The fire burns through floor joists or roof beams and these collapse under their normal load.
2. The floor load is increased by the weight of water absorbed by contents, causing the floor joists to give way. This result can be hastened when the joists are fire-weakened.

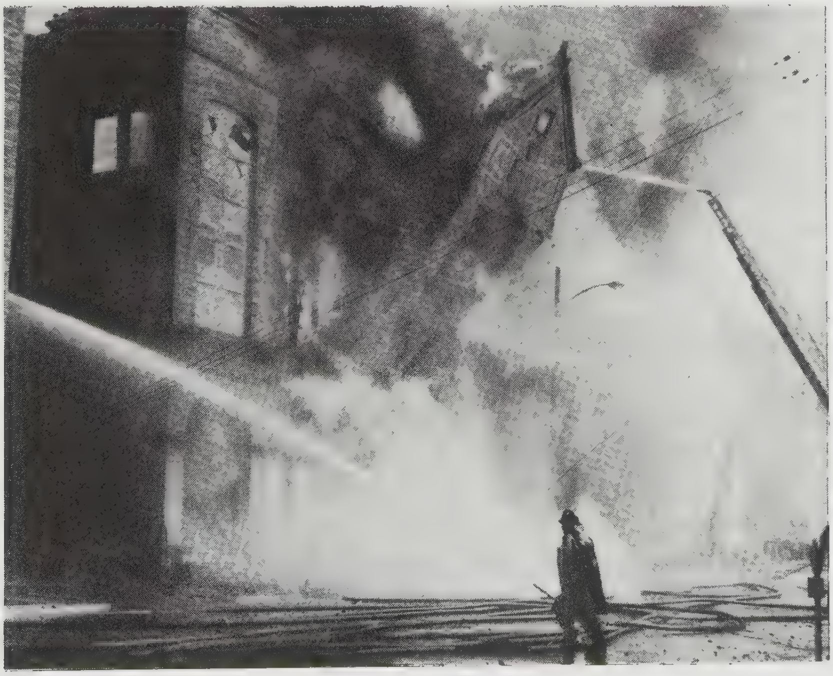


Figure 9.15. *Some buildings can collapse quickly and with no warning, endangering life and possibly extending the fire. Multi-story, non-residential, brick and wood joist types are susceptible.*

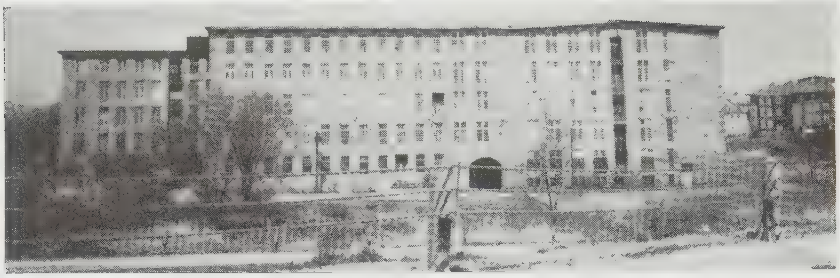


Figure 9.16. Slow-burning or mill construction building combines brick walls with extra-heavy wood floors, beams, and columns. "Slow-burning" means that structural integrity is not destroyed quickly.

3. Some fibrous materials expand when wet and push out the walls.
4. Fire gases or escaped commercial gases or vapors explode.

The first problem above can be expected in a commercial (industrial or mercantile) building of wood joist construction when fire has been burning out of control for more than 20 minutes (Figure 9.15). How do you know how long it has been burning out of control? You can't tell for sure, except that you know how long it has been burning after your arrival, and can guess from what it looked like when you arrived how long it had been burning vigorously then. Another accepted rule of thumb is to back out if there is considerable fire on more than one floor. Collapse is likely. These guidelines are meant for industrial or mercantile occupancies in brick and wood joist buildings (so-called ordinary construction). They do not apply in dwellings or multiple dwellings, which are much less prone to collapse, or to commercial buildings of other construction types and occupancies where collapse is also a much more remote possibility (Figure 9.16).

COLLAPSE FROM WATER

The accumulation of water can overload floors to the point of collapse, and this result is most likely where absorbent materials, which will hold the water and build up the weight load, are stored. A 2½-inch hose line discharging 250 gpm can put a ton of water into a building each minute. Ten times that volume will give ten tons per minute. If a substantial portion of this water remains on a floor, that floor can be soon loaded past its capacity. Ordinarily, water will not accumulate any deeper than the height of the doorsill, unless absorbed by absorbent contents. The run-off can be determined by observing the bottom of stairs and other shafts.

Another cause for collapse lies in the expansion of some fibrous materials when they absorb water. There have been cases where such materials have expanded enough to push out the walls of a building. The materials which are most likely to absorb large amounts of water are baled cotton, wool, paper, jute, kapok, and similar materials, including rags. In occupancies where such materials are stored, always consider the possibility of collapse due to water absorption.

Dwellings are not prone to collapse. Usually, even when allowed to burn freely, they just burn away and eventually, when very little is left and no interior firefighting would be feasible, there is failure of structural members—but nearly always it is slow and gentle. The only sudden collapse hazard is that of a corbelled or supported chimney when the fire is either well advanced, or the chimney support (sometimes only wooden two-by-fours) has burned away.

Ⓣ Sprinklers are
98% effective

10

Sprinkler Operations

SPRINKLERS ARE one of the best weapons yet devised to combat fire, but any weapon—no matter how good—must be used correctly to get the best results. Sprinklers, in order to function at maximum effectiveness, often need the help of the firefighting force. Eighteen percent of the "large-loss" building fires occur in sprinklered buildlings. Usually human failure, rather than sprinkler failure, is to blame for such losses. The rapid extension of one of the costliest fires in United States history can be attributed to the failure to use the sprinkler system properly. (A sprinkler control valve was hastily closed before the fire had been extinguished, and soon the flames spread beyond control.)

Another illustration of human failure was shown when a fire department did not supply water to a sprinkler system because the building's siamese connection was obscured by a pile of bricks. After the water from the gravity tank was exhausted, the fire extended rapidly throughout several floors of what was thought to be a fire-safe modern building.

Officers must anticipate the problems that may arise when fire occurs in a sprinklered occupancy and prepare themselves to operate in a manner that will not only cope with these problems but will make good use of the sprinklers (Figure 10.1). In this regard, there are two main divisions of activity: *(1)* operations at the fire and *(2)* preparation before the fire, which includes inspection and pre-fire planning.

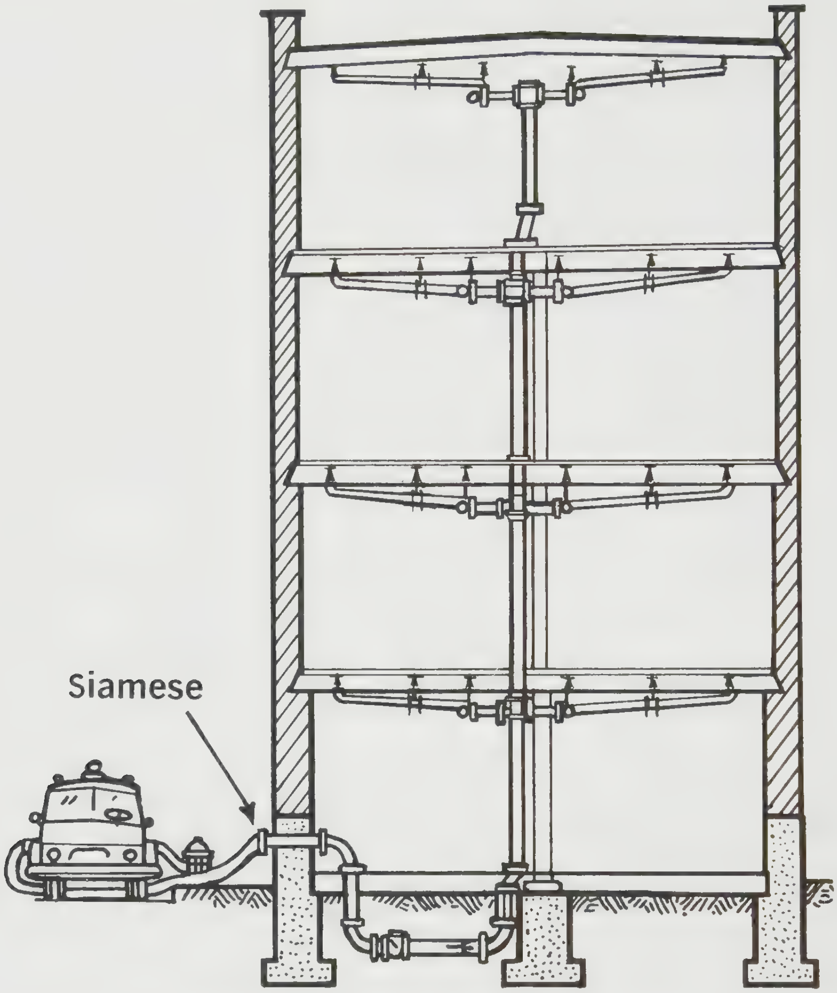


Figure 10.1. *The simplified sprinkler system shown here demonstrates the arrangement for fire department use. The public main feeds a pipe running through the center of the building.*

Inspections help firefighters discover unsafe conditions affecting the sprinkler system, such as valves that are closed or inoperative, defective siamese connections, inadequate water supply, sprinkler heads corroded, covered with paint, or blocked by obstructions that would seriously limit their effectiveness, and the storage of materials that would react dangerously with water.

Fire department inspectors should also look for the sources of supply and the location of control valves—especially those that would be difficult to find during a fire. The locations of siamese connections that fire department pumpers use to supply the sprinklers should be noted and differentiated from standpipe and other inlets. Also, if there is a split system, it is important to know what portions are supplied by the various inlets.

The task facing the fire department at a fire in a sprinklered occupancy is not always simple. For one thing, the high humidity caused by the sprinkler spray causes the heat to be extremely distressing to firefighters, and the water-laden smoke descends to the very floorboards—sometimes even to floors under the fire—making it virtually impossible to avoid the smoke by getting under it. Operations are hampered by discomfort and poor visibility. It is largely for these reasons that firefighters often prefer to close the sprinkler system quickly and extinguish the remaining fire with water from hose lines. But this practice can be dangerous.

If "wet" smoke is a problem, correct ventilation may remove it. Due to the weight of the smoke, top ventilation is not as effective as in other cases; however, much may be accomplished by good cross-ventilation, especially if it is assisted by blower and exhaust fans.

When it is determined during a fire that there is no longer any need for the sprinklers, they should be closed without delay to avoid additional water damage. Whenever a valve is closed, however, a firefighter should be stationed at that valve ready to open it again at a moment's notice. Furthermore, he should remain at that post until the used sprinkler heads are replaced and the valve reopened—even if this assignment means leaving him behind when the companies return to quarters.

Should a fire be so large that there is no question of shutting off the sprinkler system, then attention should be directed to augmenting it. If the water is supplied from a gravity tank, pressure tank, or other limited source, it may be used up quickly. Most systems have one or more fire department supply inlets. When one is available, a hose line from a pumper should be connected to it at every fire and water

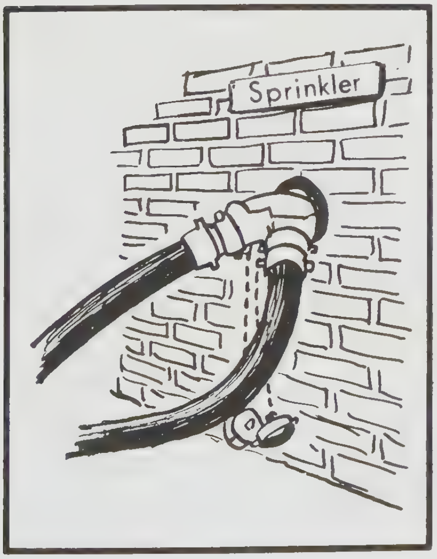


Figure 10.2. *When a sprinkler supply siamese is available, it is good practice to connect a line to each inlet. The two lines reduce friction loss considerably and provide a margin of safety should one burst.*

supplied in the necessary amount. If such an inlet is a siamese, it is good practice to connect two hose lines—one to each side (Figure 10.2). Two lines reduce friction loss and provide a safety factor should one burst. Pumpers that are supplying sprinkler systems should not have too much of their water diverted to other uses, such as hand lines or deluge sets; this precaution is particularly important when many heads operate. A similar problem occurs when a pumper uses a hydrant that is connected to the same main supplying the sprinklers; frequently there is not enough water for both. Officers should be alert to this possibility. Some fires have extended because pumpers "robbed" the sprinkler system. Careful judgment is called for to decide where the water will do the most good—from the sprinklers or from the hose lines—when there is not enough for both.

SPRINKLER FLOW

Remember that volume rather than high pressure is required to supply sprinklers. Excessive pressure may cause a rupture in the piping and render the whole system useless. A pressure sufficient to maintain 10 psi at the highest and farthest fused head will be ample in most situations. Volume, however, must be estimated to calculate friction loss allowances. A simple formula for estimating the volume of water needed to supply a number of sprinkler heads in a fire area is: $Q = A \div 4$, where A is the area in square feet and Q is gallons per minute needed.

An estimate of the friction loss in the piping can be had from a very simple formula of one pound for each foot of pipe. This allowance of ten pounds pressure loss for every ten feet of pipe (or one pound per foot) is adequate, and friction loss is only of concern when a large number of heads are operating. With a few heads operating, 30 pounds added to the pressure loss due to elevation (from the top of the fire floor down to the level of the pumper) will usually give an adequate pump pressure. With many heads operating, the one-pound-per-foot formula (from the siamese to the fire area) can be added. Note that there may be occasions when one pumper will not be enough to supply the amount of water and pressure needed.

When it appears that sprinklers are not putting out a fire, a quick check should be made of all valves to see that they are open. There is the possibility that the whole system or a portion of it was shut off prior to the fire. Firefighters should be able to identify a post indicator value or outside stem and yoke valve, and determine if the valves are open or closed; they should know how to open and close these valves (Figure 10.3).

Sign or Tags
Should I.D. Valves

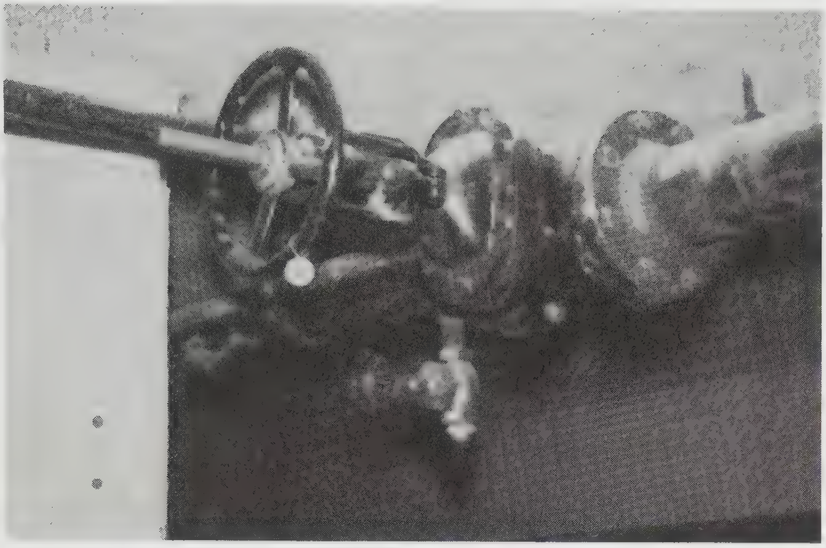


Figure 10.3. *The protruding stem on this O.S. & Y. (outside stem and yoke) valve indicates the valve is in the open position. No protrusion indicates that it is closed. The smaller pendant valve is used to drain the system when needed, such as when a new head is to be installed.*

Most fires that happen in areas protected by automatic sprinklers are quickly extinguished by the operation of one or two sprinkler heads. What then are the reasons for those rare occasions where fire spreads beyond control of sprinklers that are known to be in operating condition? One is a flash fire that sets off so many heads that the water supply is exhausted before the fire is extinguished. When this situation occurs, it is essential that the sprinklers be supplied quickly by fire department pumpers. Another reason could be that the fire is out of reach of the sprinkler spray—under a work table, perhaps, or in a concealed wall. Sometimes an explosion that caused the sprinkler pipes to rupture or fall is the reason for failure. Another possible cause is the storage of materials not readily extinguished by water.

In most cases, however, sprinklers extinguish the fire quickly and the firefighters' problem is largely one of shutting them off, which can be done by closing the control valve for the area involved or by the temporary measures of using "sprinkler tongs" or a wooden wedge to stop the flow of water at a particular head or heads. If no other means is available, one may stop the discharge from a sprinkler by holding a finger tightly over the opening until the valve is found.

Companies should be equipped with small wooden wedges of a size that can be driven into the loop of a sprinkler head assembly to cover the orifice tightly and stop the flow. In areas not serviced by salvage units, a department should carry a few sprinkler heads on the apparatus so that those fused can be replaced quickly and the system restored to service.

3-2898-1 1724 86th St. (bet. 17th & 18th avenues)
A.D.T. valve

Peerless Mattress Co.
Cellar, 1st and 2nd floors
Manufacture of mattresses, storage of
kapok, felt, excelsior, cloth.

Wet pipe automatic—city main connection
control valve in cellar 10 feet west of
entrance on 86th St. side wall.

Siamese connection on 86th St. front of
building 6 feet from west wall.

Figure 10.4. *Example of a sprinkler valve location card.*

If control valves are not marked or indicated in some way, they are often difficult to find. Sometimes they are in closets or concealed in ceiling or wall spaces accessible through small doors or panels that are not readily noticed. When the piping is visible, it may be traced by following the larger pipe at each junction until the valve is reached. In sprinklered buildings equipped with a water motor gong on the outside of the building, the control valve will most likely be found in the room right behind the gong. Wherever a control valve is accompanied by a drain valve, the drain valve should be opened when the control valve is closed.

There is a certain danger in opening the drain valve in some buildings because, if the fire rekindled after the whole system was emptied, it might take some time to refill the system. Therefore, a charged hose line should be ready in the fire area when the drain valve is open. The drain valve should be closed before the fire department leaves because building employees may forget about it.

A card file or computer information giving the location of sprinkler valves can be carried on apparatus or chief's cars; it can also carry additional information about the building and occupancy (Figure 10.4).

Fire departments often respond to sprinkler alarms in sprinklered buildings but find no sign of fire. In a large building it is difficult to find a small fire, but one step that can be taken is to determine whether or not there is water flowing. Many false alarms are due to pressure surges or electrical causes without a sprinkler head operating. If the system is a dry-pipe one and water is flowing, the pressure will show the same on both gauges of the dry-pipe valve.

In any system, wet or dry-pipe, one can find out in which riser the water is flowing by placing an ear against the pipe and listening for the sound of water moving through the pipe. In a large building where the indications are that water is flowing even though no other sign of fire is evident, it is a good precaution to hold all companies present until the cause of the alarm has been found. Some officers are reluctant to force entry in such circumstances, and large-loss fires have resulted in consequence.

Another desirable precaution is to connect a line from a pumper to the siamese connection of a building that is severely exposed to a fire next door. If the fire suddenly extends into the exposed building, it may fuse a large number of heads simultaneously and overtax the system's normal water supply. With a pumper already supplying the system, the efficiency of the sprinklers can be maintained.

On occasions, fire departments are called upon to restore sprinkler systems to use after they have been activated by a fire or other cause. Normally, sprinklers will continue to discharge water until shut down, but sprinkler systems are now available that will shut down automatically when the fire has been extinguished and reactivate if the fire rekindles. This innovation is a great boon to fire protection and will probably supplant the older systems. Until that lucky day, however, most sprinkler systems will require manual attention for shutdown and reactivation.

The restoration of sprinkler systems and replacement of fused heads may have to be performed by the fire department; therefore an understanding of the various systems is desirable.

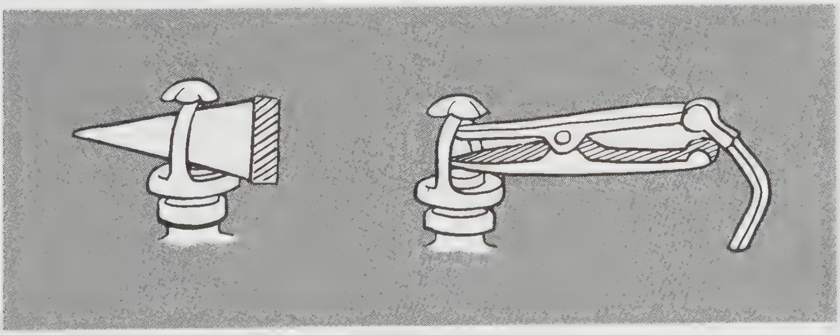


Figure 10.5. *Special tongs or a wooden wedge can be used to shut off a sprinkler head. The tongs are placed inside the head and released; the wedge is forced in until it is tight.*

AUTOMATIC WET-PIPE SYSTEM

This type of system is equipped with discharge heads controlled by fusible links of metal or quartzoid set to melt at a predetermined temperature, usually 135° or 165°F. (Higher temperature heads are available.) The system is kept full of water under pressure. When a fusible link is melted by the heat of a fire, the water discharges through the opening left by the displacement of a plug that the link restrained. The water will continue to flow from a fused head until the water supply is exhausted or shut off.

The restoration of the system entails the following steps:

1. Shut off the supply valve.
2. Open the drain valve (to release water in the pipe between a fused head and the supply valve).
3. Replace the fused head or heads.
4. Close the drain valve.
5. Reopen the supply valve.
6. Before leaving the premises, make sure all supply valves are open and drain valves closed.

AUTOMATIC DRY-PIPE SYSTEM

In outside areas or unheated interiors where freezing temperatures may be encountered, dry-pipe systems are used to prevent freezing of water in the pipes. As the name implies, the piping in this system is kept dry (full of air) until the heat of a fire fuses a head. As the air escapes from the opened head, the pressure of the air in the piping decreases until it is less than the water pressure on the other side of a dry-pipe valve. Then the valve opens and water flows into the system and up to the open head. (Of course, this process is much slower than the wet-pipe system.)

Restoration of a dry-pipe system is not as simple as that of a wet-pipe. The dry-pipe valve, which is kept in a heated area, has water under pressure on one side and air under slightly higher pressure—to keep the valve closed—on the other side. There must be a compressor to keep the air pressure constantly above that of the water. Some systems establish the pressure differential with an air pressure lower in psi than that of the water. This is accomplished by giving the air side of a valve greater area than the water side so that the total pressure on the air side is greater.

Once a dry-pipe valve is tripped, it is held open by a catch until restored manually. The air pressure and water pressure are shown by gauges.

Restoration may be performed as follows:

1. Close the supply valve (not the dry-pipe valve).
2. Open the main drain valve and drain the system completely.
3. If there are any points below the main drain, drain them separately.
4. Remove the hand-hold cover from the dry-pipe valve (which is a clapper type).
5. Raise the spring latch and return the clapper to its seat.
6. Replace the hand-hold cover and fasten it securely.
7. Open the priming cup valve and priming water valve to let water into the dry-valve body until it reaches the level of the priming water connection.
8. Remove excess priming water by opening the draw-off valve (usually at the bottom); then close this valve.
9. Replace fused heads.
10. Close small drains.
11. Admit air into the system according to the manufacturer's recommendation. (If no recommendtion is available, air pressure can be set at about 30 percent of the water pressure on a high differential system or slightly above water pressure on a low differential system.)
12. Close the main drain valve.
13. Open the supply valve.
14. Make sure all drains are closed and all supply valves are open before leaving the premises.

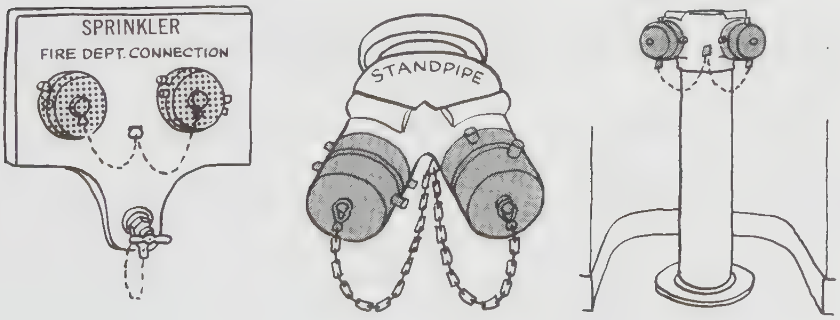


Figure 10.6. *Sprinkler and standpipe connections should be easily and definitely identified. New York City requires that standpipe connections be painted red and sprinklers green for ready identification.*

The reason for checking to see that all supply valves are open after the system is restored is because sometimes in the excitement more than one valve is closed. I remember a case where factory personnel closed three valves before finding the right one, but after the sprinkler head was replaced they only reopened one.

DELUGE SYSTEMS

Needs:
Heat
Detection
Device

Deluge systems are of two main types: open-head and sealed-head. The heads of an open-head system have no fusible links. They are always open; therefore the piping must be kept dry until the system is activated by a heat detector. The sealed system is also activated by a heat detector, but the heads are kept closed by fusible links until they are melted. In the open-head system, water discharges from all heads, but in the sealed system it comes out of only those heads which fuse.

Both systems are usually dry and are restored by the resetting of a dry-pipe valve and, in addition, a release. The release is reset by pulling outward on the reset lever and lifting the release weight until it engages the weight-releasing lever.

It should be understood that the steps given here are simplifed and are merely meant to help the fire department restore a system temporarily when there is no one else present who knows how to do it. In some cases, the system may vary somewhat from those described here, and alarm valves might need separate reactivation. Therefore the fire officer should make certain that the proper representative of the building owner (usually the custodial engineer) is notified of just what happened so he can supplement or correct the actions of the fire department.

NON-AUTOMATIC SYSTEMS

There is another type of system, usually found in very old buildings, but sometimes accepted as a compromise in modern structures—especially in store basements: the non-automatic system. It never contains water except that pumped into it by the fire department during a fire. The replacement of fused heads is the only restoration necessary, other than draining. Due to the nature of the system, restoration does not have to be immediate and can wait for the attention of building employees.

Some of these non-automatic systems have open heads or perforated pipes. Thus, when water is put into the system, the water comes

Approximate Flow Rates

Sprinkler Pressure (psi)	*½-inch Sprinkler (gpm)*
10	18
15	21
20	25
25	27
35	33
50	40
75	48
100	55

Figure 10.7. *Approximate flow rates of sprinklers.*

out all through it. Officers should therefore make sure they are supplying the system that protects the fire area. In some cases there are different systems fed by different inlets within the same building; usually, this condition is found where there are sub-basements, each fed from a different inlet. The consequences of feeding the wrong inlet could be considerable unnecessary water damage; therefore, it is desirable to require such open systems to be identified as open and also to identify the area served. Sometimes the location of the fire can be determined by removing the caps from the siamese connections and sniffing for smoke (while the clapper valve is held open).

The care and maintenance of sprinkler systems are not within the scope of this book, nor is it appropriate for us to go into the relative merits of each type of system or other aspects that are engineering rather than operational in nature (Figure 10.7). There are accelerated dry-pipe systems and other refinements of the basic types discussed here, but the purpose of this chapter is to provide fire officers with the knowledge that will enable them to take the proper steps to operate efficiently in the sprinklered properties to which they respond.

11

Ladder Company Operations

EVEN BACK in the early days of American firefighting, the personel assigned to apply water were separated from those needed to perform the various other duties required on the fireground. The engine and hose companies assumed the tasks of taking water from available sources and applying it to the fire. Other units, designated "hook and ladder" companies, were assigned the remaining firefighting jobs. Some departments still refer to these companies as "hook and ladders," while others call them "ladder companies" or "truck companies."

Whatever the nomenclature, the duties are mostly the same in all fire departments which have such companies designated as different from the engine units. The most truly descriptive—but very unwieldy—designation would be "forcible-entry, search, reconnaissance, rescue, ventilation, and overhaul company." Most of these duties have been covered separately in other chapters. For those who like acronyms, these words can be rearranged to spell "Rovers," a rather apt description of their duties (see Figure 11.1).

These tasks are the principal duties of such units. All are important. Neglect of some of these duties could result in the loss of control of a fire—and it often happens. When ladder company duties are not definitely assigned, they are frequently overlooked altogether, or not done to an adequate extent.

Figure 11.1. *It is unfortunate that a properly descriptive name has not yet been given to the companies presently called ladder, hook and ladder, or truck companies. Recently, on television news a chief said, "We sent the truck to the roof to ventilate." This statement must have mystified many viewers. An appropriate term can be derived from an acronym of their duties. It is "ROVERS":*

R —Rescue
O—Overhaul
V —Ventilation
E —Entry
R —Reconnaisance
S —Search

They also raise ladders when necessary.

An interesting experiment was conducted by our Wisconsin training program to discover if there were any common weaknesses in volunteer fire departments. The five fire departments that participated were about average in that they had ample funds, equipment, and personnel, yet notable deficiencies appeared which were common to all five fire departments in the tests.

In the experiment, the participating departments were called, each to its own separate "fire" to operate as they saw fit. Six visiting fire chiefs were stationed throughout the fire area to note the performance of each department. When the chief of the department who was assigned to the fire declared the fire completely extinguished, the critics (visiting chiefs) would turn in their reports.

SAME COMMON MISTAKES

The fire building was ideal for such testing. It consisted of several stores on the ground floor of a two-story wood frame building, with apartments on the floor above. In all five cases, the same mistakes were made. Briefly enumerated, these errors were:

1. Almost all the activity involved the application of water. Eight men would be holding a 1½-inch hose line while all the other duties were forgotten.

2. Ventilation was sadly neglected. Windows remained unopened while firemen were groping and coughing in the smoke. It seems ironic that someone who would quickly open the doors and windows at home to let out the smoke when a roast had burned would not think of doing the same thing at a fire.

3. There was little or no search. In each of the five fires, a dummy was hidden on the second floor, but it was never found because nobody looked for it. Unfortunately, the same would probably have been true at a real fire.

4. There was little or no attempt to discover fire extension. In one case, no firemen went to the second floor until 15 minutes after

arrival. By then, the fire had extended upstairs in three different places.

5. Overhauling was definitely insufficient. In one case, there was hidden fire in a cornice in the front of a store. In another, fire was still burning in a ceiling. Yet the chiefs in charge of these fires had declared them to be extinguished. It made one wonder what percentage of rekindles these departments had at home.

All these deficiences can be attributed to the fault of not preassigning ladder company duties. The best assignment is pre-fire assignment. In fire departments where the non-water-applying duties are pre-assigned, they get done. When they are not definitely assigned before the fire, they are often neglected, if not overlooked completely.

It is not necessary that a separate ladder company respond to perform these duties. A shiny new ladder truck doesn't make a ladder company; long ladders are not frequently required. Tools and knowledge are the main requisites for ladder company work.

Ladder company duties can be itemized as follows:

1. Opening locked doors to permit entry for search, rescue, ventilation, and application of water
2. Opening windows, skylights, doors, and other coverings to allow the escape of smoke, heat, and fire gases
3. Cutting holes in the roof of the fire building to speed the escape of heat, smoke, and fire gases
4. Using smoke ejectors to aid in the ventilation described in items 2 and 3 above
5. Searching for persons overcome by smoke or otherwise in need of assistance
6. Removing persons in danger to safety
7. Searching for extension of the fire
8. Opening partitions, ceiling, and so on, to allow engine companies to put water on fire in concealed spaces
9. Raising ladders when needed to accomplish all of the above items and to allow engine companies to take hose lines to upper floors
10. Overhauling, i.e., opening ceilings, walls, floors, and examining burned furniture, stock, and other contents of the premises to make certain the fire is completely extinguished, and restoring the occupancy to a condition as reasonably close to its pre-fire status as circumstances will allow
11. In some fire departments salvage duties are assigned to ladder companies, which is all right if it doesn't impede their more important work. At any rate, the ladder company should be prepared to look for sprinkler shut-offs and turn them on or off as needed.

12. Simultaneously with their other activities, the crews performing ladder company duties must be conscious of their reconnaissance responsibility. They should report any discovery or observation which might interest the officer in charge of the total firefighting operation, including safety hazards, extension of fire, need for special attention, or any other item which could have a bearing on the outcome of the fire or which might help determine its cause.

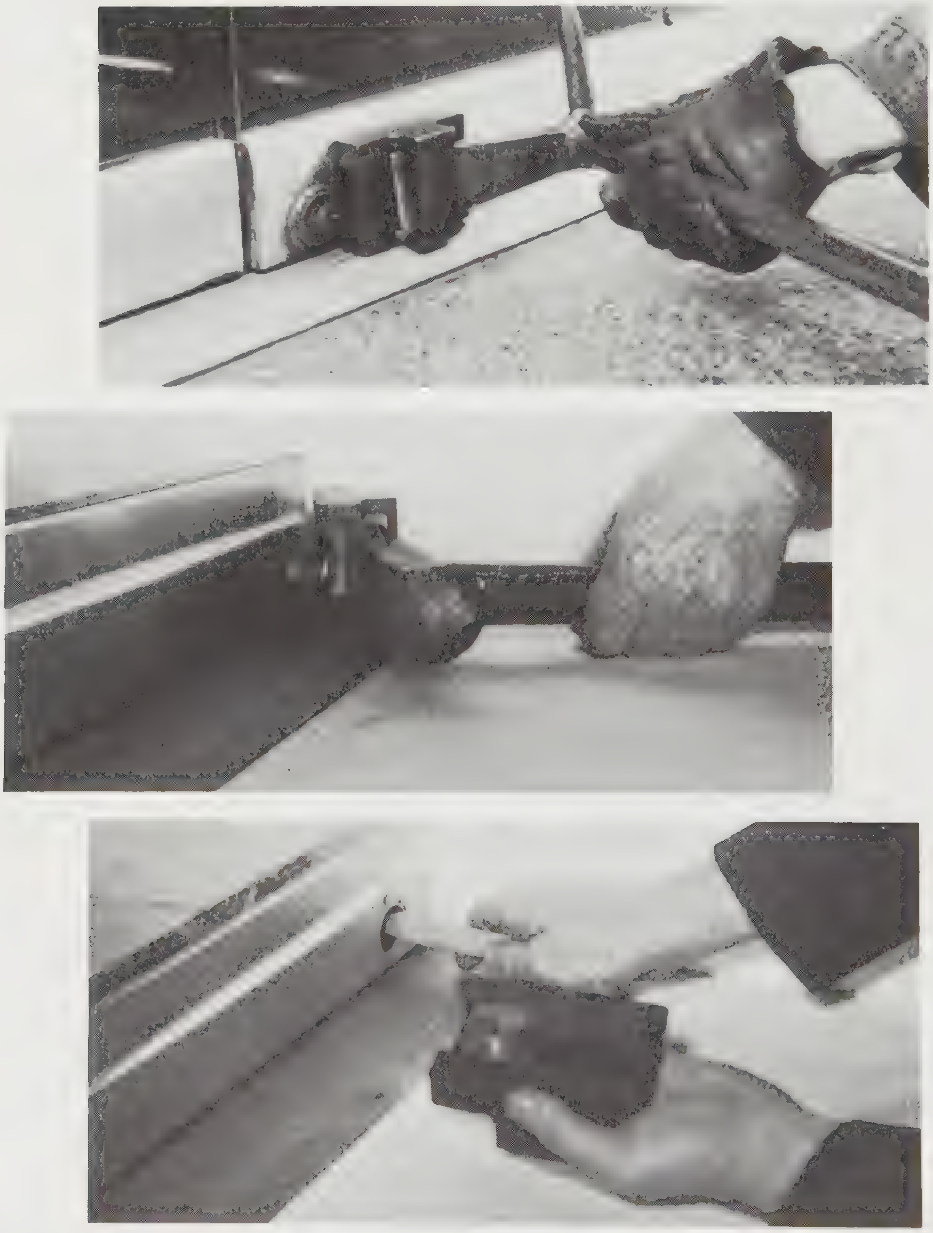


Figure 11.2. *The K-tool opens the lock on a glass door. A halligan bar or similar tool provides the force.*

The engine company does its work with hose lines; the ladder company with tools. In the larger fire departments, the tools are preassigned so that at the moment the truck arrives at a fire and the firefighters step off, each carries a specified tool. The commonly carried tools are: ax, six-foot pike pole, a forcible-entry tool such as the claw tool, halligan tool, or some similar multi-purpose tool, and perhaps a specialized tool, for opening locked doors (Figure 11.2). Of course, the number of tools brought in depends upon the number responding, but with each one carrying two tools, three firefighters can furnish the necessary complement for most tasks.

A common misconception is that the ladder company members should remain together and work as a unit. This procedure may be proper for the second-due or later-due ladder companies, but the first-due ladder company should usually disperse in a prescribed manner, with its members distributed so that the roof, the rear, the fire floor, and the floor above it are all covered simultaneously or as close to it as available personnel will permit. A ladder company without sufficient personnel for simultaneous coverage of these four points is understaffed. Frequently, all these places can be reached without resorting to the time-consuming task of raising ladders. The stairs, fire escapes, and adjoining buildings often provide the best way of access.

The main reasons for one of the ladder company going to the fire floor are to force entry for the engine company if locked doors are encountered and to open ceilings or side walls to allow them to get water on hidden fire. The members going to other locations (roof, rear, floor above fire) are sent principally to ventilate and search for occupants and extension of fire.

LADDER COMPANY POSITIONING

The question naturally arises—and is often the subject of debate—as to where the officer of the ladder company should be stationed. Some feel that he should go with the engine company to the seat of the fire. The argument for this opinion is that he can better determine what work is required when he gets a close look at the fire and then can call for the needed tools (and the individuals carrying them) when they are wanted. Against this belief is the reasoning that the engine company officer is already in the immediate fire area and that the ladder officer could be more useful elsewhere until the fire is darkened sufficiently for overhaul to begin. But where else would he be better able to perform his duty of directing and supervising the firefighters under his command? If there is a difficult job of forcible entry, he should be there to direct it. If no chief officer has arrived, he can reconnoiter and find where the danger points are. He can also do this at the rear of the building when only one chief is present and is in the front.

Another option that the ladder officer has is to take the position he considers most important in the particular situation, whether it be the roof, the floor above the fire, or even an adjoining building if there seems to be a likelihood of fire extension. (If, however, he shows a pattern of affinity for the least hazardous positions, it will probably be noticed by his subordinates and superiors alike.)

Even when the first-due ladder company arrives after a chief officer, its routine duties still can be carried out without specific orders from him, unless he states otherwise. The duties of ladder companies, other than the one first due, however, are usually assigned by the officer in charge of the fire to suit the needs of the occasion. Furthermore, ladder companies other than those first due usually remain together and work as a unified group after receiving directions.

Ladder company members must be trained to be observant and exercise initiative. They should be encouraged to use good judgment and allowed to take actions they think necessary without waiting for orders. For instance, if a firefighter is sent to the roof by himself, he should not have to go back down to ask an officer if he should remove a skylight. The firefighter sent to the roof should have enough experience or training to know whether or not conditions warrant removal of the skylight and also what other duties to perform before leaving the roof. The same holds for the firefighter at the rear of the building. If the windows cannot be opened, he should have the authority to decide whether or not he should break the glass. Valuable time could be lost if these company members had to seek approval before taking action. Furthermore, unless the officer went to look for himself, he would not be in a good position to make the right decision.

The members of the first-due ladder company—and other ladder companies, too, on occasion—based upon reasonable interpretation of department policy and training, should have the right to do whatever seems necessary without waiting for specific orders. They should, however, report their actions to their officer as soon as feasible and inform him of any actions taken or needed.

Because of the urgencies of firefighting, they should be free to bypass the chain of command if their immediate supervisor cannot be found quickly. It would be ridiculous for a firefighter to run past a battalion chief three times while looking for his company officer to report that the fire is extending into the building next door.

NECESSITY OF ASSIGNING TOOLS

The pre-fire assignment of positions should go along with the pre-fire assignment of tools for the ladder company first due. The key positions such as the roof, the floor above the fire, the top floor, the rear of the building, and the fire floor, should be given out before the fire. Members should, of course, understand that these position assignments are to be followed when practical, but not when the situation obviously does not call for them, such as at a fire aboard ship or in a truck on a highway. The pre-fire assignments are generally for fires in the types of buildings most common in the district served. Other situations will have to be dealt with upon arrival; however, the assignment of a complement of general-purpose tools is called for in most situations.

When position assignments are not given out until arrival at the fire scene, there is a chance that the ladder officer may forget one of them due to the stress of the fire situation. Assignments can always be changed on arrival at a fire that indicates a need for a change in tactics.

As an example, New York City once had the custom of having the chauffeur and tillerman of the first-due ladder company raise a 20- or 25-foot ladder to the front of the fire building. Only once in a great while would this ladder serve a very useful purpose; most of the time it was useless; sometimes the ladder was an obstruction. In certain situations, such as a fire on the sixty-seventh floor of a tall building, it was downright ludicrous. Yet the practice was followed religiously without question, often at the cost of more important duties having to wait. Incredibly, there was no reference in the rules and regulations or the official action guide. It is worthy of mention here because it shows how tradition can bind a fire department. I was so intrigued by the practice that I undertook to find out how it originated. I couldn't accept the reasons offered:

"It marks the fire building for incoming companies." When flame is showing from several windows and a hose line is going in the front door?

"It provided a ready escape route." From Grand Central Station?

There must be a more compelling reason, probably founded on tradition. An old captain provided the answer which made the most sense. He said, "It is a holdover from the days when the volunteers used to fight over which truck company 'had' the fire. They agreed that the fire belonged to the one that got the first ladder up to the building."

The point is that we should re-examine our tactics occasionally to determine whether or not they are still valid. Not many years back, some of our larger fire departments still had 35-foot straight ladders on their aerial trucks. This practice was definitely a holdover from the nineteenth century when a ladder of that size nicely reached the third-floor windows of the mercantile and industrial buildings of that period. It did not fit well with twentieth century architecture, yet it went unquestioned.

In recent years there have been changes in the vehicles used by ladder companies, but the functions of these companies have little changed. The articulating boom elevating platform was adopted from industrial use and brought into the fire service in Chicago in 1958. Although its acceptance was slow at first, it eventually caught on and can now be found in hundreds of fire departments. It was followed shortly thereafter by the telescoping boom platform (tower ladder) which was introduced in New York City and is now in use in many areas.

The platform has not fully supplanted the aerial ladder (Figure 11.3). Each has a place where it excels the other. The aerial ladder can

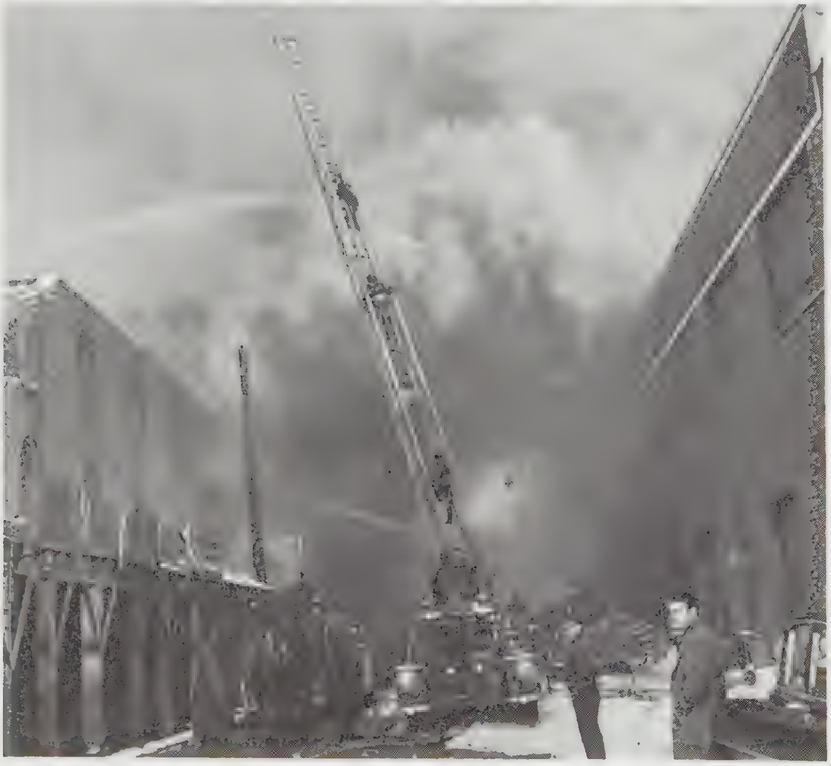


Figure 11.3. *American-made aerial ladders are marvelously strong. Assuming a nozzle pressure of 80 psi on this ladder pipe, there will then be a 270-pound nozzle reaction. This value, multiplied by the height of the nozzle, gives the forces working to push the ladder away from the building. Offsetting this complex of forces is the weight of the ladder, the hose and the water in the hose, and the firefighters on the ladder.*

be raised more quickly than the platform and is fine for rescue. But the platform is unexcelled in the application of water to heights. Chicago fire officers swear by their "snorkels." In New York, the "tower ladders" are regarded as the best weapon the fire department has.

The question arises as to whether the platforms should run as ladder companies or as special apparatus. Most cities equip platforms with ground ladders and tools and run them as ladder companies. It should be recognized, however, that the main strategic value of the tower ladder and elevating platform lies in their ability to apply water. The question then arises as to whether they are truly a ladder company apparatus or not. They probably will be used for the application of water more frequently then for rescue and ventilation. Still, their value does not lie in that area alone, and both types are generally regarded as ladder company apparatus even though they may be at their best applying water.

USE OF GROUND LADDERS

It would be well for fire chiefs to review their use of ground ladders to determine the most suitable lengths. Most of the "standard" lengths of today's ground ladders were arbitrarily set more than 60 years ago. Some fire departments have been getting along nicely for years without any ground ladder longer than 35 feet; others still carry a 55-foot extension ladder which, in most cases, they don't have the personnel to raise.

Also due for re-examination is the practice of raising a certain number of ladders—whether needed or not—at all building fires. The time for a drill is not at a real fire, and there are few departments left with enough ladder company personnel to go through such a routine without sacrificing more important duties.

Another item that should be reconsidered is the so-called "proper" angle for ground ladders, commonly accepted as being arrived at by placing the butt away from the building face a distance equal to one-quarter of the height to which the ladder is raised. Today's metal ladders are strong enough to be used at less steep and safer angles. It also makes a difference as to whether the ladder is to be used for rescue or application of water. In the latter case, a less steep angle would be desirable, due to the nozzle reaction tending to push the ladder away from the building.

Some fire departments use ladder "dogs"—in this context, a short chain with a hook on one end. The hook is dropped in a window and the other end of the chain is attached to the ladder. This device keeps the ladder from falling away from the building, but it also keeps the ladder from being moved in a hurry—or at all—if flame shoots out the window.

Today's metal ground ladders are not made to resist more than 400°F, yet that temperature is not hot for a fire. Such ladders are vulnerable to flame, even during a short exposure.

Officers should use care in selecting the sites where ladders are to be raised and observe the safety precautions mentioned in an earlier chapter, especially in regard to electric wires. Metal ladders conduct electricity, and firefighters have been killed because of it.

Aerial ladders must be positioned with several thoughts in mind:

1. *Exposure of the ladder to fire:* The ladder will be useless for rescue or access if no one can climb down or up it because of flames shooting out from windows under the ladder. Not merely flames showing at the time of raising need be considered, but also the probability of later exposure while someone is on the ladder. An aerial ladder can be positioned at an angle almost parallel to the building to reduce such danger.
2. *Need for the ladder to be moved:* Sometimes the aerial ladder will be needed at more than one spot, or even for more than one purpose. For example, the ladder may be used first to remove occupants from one of the upper-floor windows and then raised to the roof for the access of firefighters seeking to ventilate, or it might be used first for rescue or access and later for a ladder pipe. If the apparatus is well placed to begin with, it may not be necessary to move it to reposition the ladder, which would save considerable time.
3. *Stability and safety:* American-made aerial ladders are marvelously strong, but they have definite limitations which each manufacturer takes care to spell out. Aerial ladders have collapsed on several occasions. Most of these occurrences were due to efforts to use the ladder in a position not in accord with the manufacturer's recommendations. Considering all the times these ladders have been used improperly, it is a wonder they haven't collapsed more often. Oddly, on many of the occasions that they have been used improperly, there was no need for them to be used at all. There is an excuse in abusing an aerial in order to save human life, but there is no excuse for doing so when the ladder isn't needed. This possibility brings up the fourth consideration, but the one that must be treated first.
4. *Is the aerial ladder really needed at this fire?* If the answer is "yes," put the apparatus in a good position. If it is "no," park it

> out of the way of operations and other apparatus. (Nothing can clog up the fireground like a vehicle 50 feet long!) If the answer is "maybe," the truck should not be driven past the fire where it would have to be backed into position later or driven around the block; these procedures are not desirable and can be avoided by parking on the near side of the fire.

The aerial should not be raised unless there may be a use for it, but we find many fire companies raising their aerial at every fire. This practice has several drawbacks. The time and personnel could be better spent on other duties, the chances of injury and mechanical damage are increased, and there will be delay in moving the apparatus if it is needed elsewhere.

At the opposite extreme is the practice in many paid, small departments whereby the truck is left in quarters except when the officer in charge of the fire sends for it. This system has its drawbacks too. In some cases, it could be argued that the one left behind to drive the truck could increase the fireground personnel by as much as 20 percent if responding on the first alarm. Lives might be saved by quicker arrival of the truck, and other work which calls for the aerial ladder could be started earlier.

In defense of the practice, there are the arguments that, statistically, an aerial ladder is rarely used, and that driving such a vehicle is a very expensive way of transporting one firefighter to a fire.

Many of the larger cities have two ladder companies respond on every building fire. There are two main reasons for this: the first is to ensure that in case of accident or breakdown to one of the trucks, the other will get to the scene. The second reason is that at a significant percentage of fires there will be plenty of work for both companies.

For this latter reason, some fire departments spell out the duties expected of both the first-due and second-due companies. The procedures that follow are offered as an example.

Ladder Company First to Arrive

Officer shall determine height of building, location of fire, location of fire escapes, and probable floor layout. He shall also size up the need for ladder company duties and establish priorities. His company shall, when necessary:

1. Remove obviously endangered persons.
2. Force entry.
3. Search the fire floor for endangered persons.
4. Ventilate at the roof.

5. Lower fire escape ladders.
6. Check the sides and rear of the building for endangered persons and extension of fire.
7. Raise ladders if needed.
8. When a chief officer arrives, the truck officer shall report to him what he has discovered and what actions have been taken.

Ladder Company Second to Arrive

If a chief officer is present, report to him for assignment. If no chief is present, do the following:

1. Search all floors above the fire for occupants and extension of the fire.
2. Ventilate as needed while searching.
3. Place ladders where needed, either by moving the ladders that were raised by the first-arrived ladder company or by raising other ladders.
4. Check the perimeter of the building and the bottom of shafts for people who may have jumped to escape the fire.
5. The officer of this company shall see that this work is carried out, and, when it has been completed, report to the proper chief officer present, advising him of the conditions discovered and the work performed.

NEED FOR SCALING LADDERS

Recently there have been some fires in high-rise buildings in which scaling ladders could have proved valuable. It was candidly admitted in these instances that the fire department had no rescue capability above the 100-foot level.

It is time-consuming, of course, but the use of a scaling ladder can extend the rescue capability to any floor of a building. Two firefighters, for example, can carry a scaling ladder to the top of a 100-foot aerial ladder and from there hook into the floor above and climb to that floor or any other floor by repeating the operation. Two firefighters can also initiate this evolution from ground level, starting with the second floor—even on smaller buildings where access is denied to aerial or ground ladders. In a pinch, one firefighter can do the job, but it is grueling and slow.

Scaling ladders are not expensive and can be quite valuable when the techniques of using them are mastered (Figure 11.4). The fire department that can't afford aerial apparatus might do well to learn

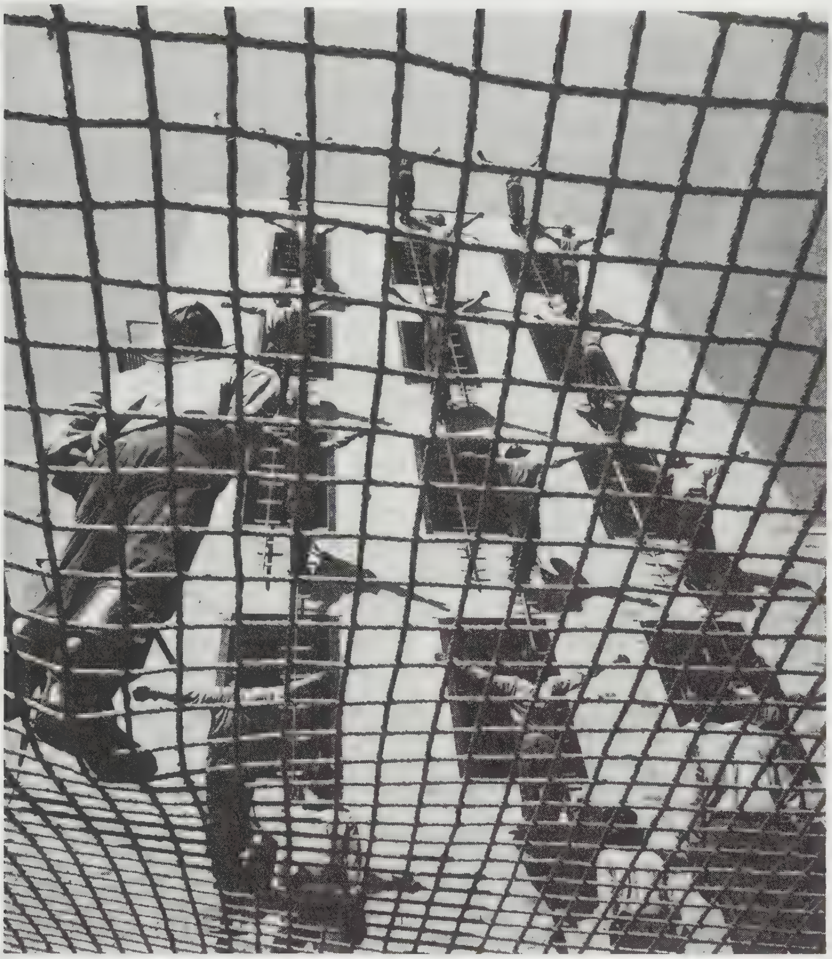


Figure 11.4. *Scaling ladders provide the last resort when aerials cannot reach a window or when windows are inaccessible to aerials or ground ladders. New York firefighters shown here are "building a chain" at probationary firefighters' school.*

about, and prepare to use, scaling ladders. The department that has aerial equipment, but also buildings beyond reach of that equipment, should also consider the acquisition and use of scaling ladders to get above the reach of their aerials.

The first recorded scaling ladder rescue was on April 7, 1884, at a fire in the St. George flats, 223 East 17 Street, Manhattan. Fireman John Binns of Hook and Ladder Company 3 used a scaling ladder to rescue Louis Costain, a 16-year-old elevator boy, who was trapped by the fire and was calling for help from a seventh-floor window.

The New York Fire Department acquired its first aerial ladder two years later, but even at that time many New York buildings towered far above the top of the new aerial. To circumvent this problem, the department developed a scaling ladder evolution in which two firefighters carry a scaling ladder to the top of an aerial ladder, and then continue up the face of the building, floor by floor, by hooking into windows. The procedure has been used at actual fires a few times over the years and has proven effective. One of the lessons learned in applying it was the advantage of bringing up a rope with which to lower the victim. It is difficult, to say the least, to take an unconscious or hysterical person down a scaling ladder. Such persons should be lowered by rope, after being properly secured.

12

Engine Company Operations

LET THERE BE no doubt that this book puts great emphasis on the non-water functions of firefighting. The reason for this stress is to emphasize their value rather than to downgrade the importance of water. We still extinguish nearly all of our fires with water. It is hard for scientific or progressive-thinking non-firefighters to digest this fact; they seem to think that technological progress should provide a better way. In fact, I once witnessed a fire in the presence of a very select and well-educated group at a convention of teachers who were dispossessed by a fire in the Hotel Roosevelt in New Orleans. As the fire went to a fifth alarm, the teachers gathered across the street to watch the fire department efforts to control it. They seemed surprised and puzzled to see that water and hose provided the only extinguishing technique; their comments indicated that they thought firefighting in the space age should be more advanced than in the horse-and-buggy era.

Those of us in firefighting might sympathize with their thoughts, but from practical experience we are resigned to the fact that the way we extinguish fires today is the same method used over the centuries—the application of water. If we are to improve our effectiveness within the scope of present-day technology, it must be through more efficient use of this elementary means. The action of water upon fire and the theory governing it have already been discussed in a previous chapter. The matter of getting water from source to fire will be discussed now.

The first item of consideration is the selection of the water source, because if the selection is wrong, all other operations will suffer. Normally, at a fire in a location that has a system of water mains and hydrants, the practice is to select the nearest available hydrant. Sometimes this choice is a serious mistake. It may be all right for the first-in engine company to take the nearest hydrant in order to get water on the fire quickly, but other companies do not have to be in such a hurry and can afford to be more selective. They can only be selective when the hydrant flow has been predetermined, and the hydrant itself has been coded by color or number to indicate its capacity. Methods of doing so have been mentioned in a previous chapter and have been spelled out in several books and publications.

HYDRANTS

Hydrant spacing, main sizes, and major system maintenance are usually beyond the control of the fire department, and some fire departments live with a poor situation. Inspections of hydrants, however, and minor maintenance are functions on which a fire department can expend time and effort with highly beneficial results. Fire departments which perform their own inspections have fewer hydrant problems than those which leave these duties entirely to a water department or a private water supply corporation. Employees of such non-fire department agencies are naturally more responsive to consumer complaints than to the fire service needs of a hydrant which they feel may not be used for months, if ever.

Identification of defective hydrants is important to prevent the loss of valuable time when an engine company connects to a disabled hydrant. Again, the New York system is clear though simple. In that city, the fire department marks defective hydrants by affixing a metal doughnut disk, painted white, to an outlet. A plain white disk indicates the whole hydrant is out of service, and a white disk with a black stripe shows that just that outlet is unusable. These disks are also used in the same fashion on the siamese connections of standpipe and sprinkler systems.

At a fire it is essential that a pumper be connected to a hydrant that is capable of meeting the needs of the occasion. Yet we sometimes see a 1,000-gpm pumper attached to a hydrant that cannot flow more than half that amount of water, while an unused hydrant around the corner could supply two such pumpers.

TANDEM PUMPING

What about putting two pumpers on one hydrant? Fine, if it can supply them, which is frequently the case. Dallas, Texas, and Milwaukee, Wisconsin, have long used so-called "tandem pumping," where two pumpers are connected to one hydrant. Many other cities also follow this practice where feasible. In fact, most Chicago hydrants have two 4½-inch outlets to permit two pumpers to connect directly to the same hydrant. In several cities it is the general practice for the pump operator of the first-in engine to connect his pumper to one outlet and put a gate on another outlet to accommodate a second pumper without having to shut down the hydrant while the second pumper hooks up.

Two pumpers can be connected to each other in such a way that the one connected directly to the hydrant gets the water it needs, and the other gets the remaining available water by connecting to an unused suction inlet on the first pumper. In this manner, two pumpers can operate at capacity if the hydrant is capable of supplying that much water.

A method of making the connection between the suction intakes of both pumpers, without shutting down the hydrant or the first pumper, is worthy of mention. The hydrant is closed until the compound gauge on the pumper already connected shows zero. Then an unused suction inlet on that pumper can be uncapped without much water escaping and the suction hose or hydrant connection of the second pumper attached to it. When the second pumper is connected to the first, the hydrant is opened fully and both pumpers can use it simultaneously.

Many engine companies use a switch valve to enable them to start water with a direct hydrant line and later connect to the same hydrant without shutting it down or losing water in the first line. One such switch valve, known as the New York switch valve, is illustrated and described in Figure 12.1.

Similar devices are used in other sections of the country. In Baltimore (and its suburbs), all engine companies carry a Meushaw valve. Miami has been using a variant of the switch valve for years. In all of these places, the objective is to get water on the fire quickly, without limiting the nearest hydrant to only one hose line—and this line with limited pressure.

An advantage of these devices is that they allow the positioning of the pumper near the fire, where breathing apparatus, tools, and other equipment will be close at hand. Of course, this task can be accomplished by stretching from hydrant to fire without a switch

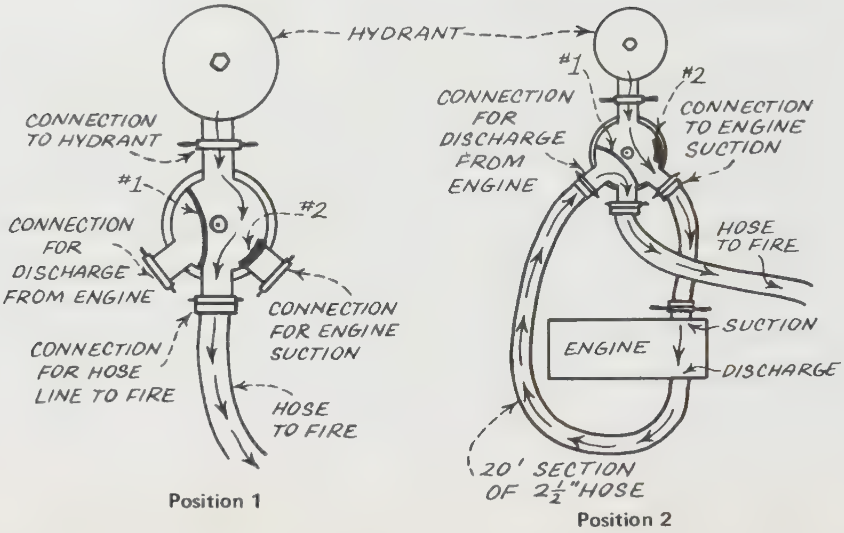

HYDRANT
CONNECTION TO HYDRANT
#1
#2
CONNECTION FOR DISCHARGE FROM ENGINE
CONNECTION FOR ENGINE SUCTION
CONNECTION FOR HOSE LINE TO FIRE
HOSE TO FIRE
Position 1
#1
#2
CONNECTION FOR DISCHARGE FROM ENGINE
CONNECTION TO ENGINE SUCTION
HOSE TO FIRE
ENGINE
SUCTION
DISCHARGE
20' SECTION OF 2½" HOSE
Position 2

Figure 12.1. *The New York switch valve.*

valve, which is a common practice, but one with risks that should be understood. Take, for instance, a fairly typical hydrant which has a static pressure of 50 psi. If a pumper lays 2½-inch hose from that hydrant to the fire, the following table shows the limitations to be expected due to friction loss in the 2½-inch supply line between the hydrant and the pumper (to provide the pumper with 10 psi at the suction inlet).

Distance (feet)	*gpm*	*Practical Limit*
100	425	Two 2½-inch lines or one deluge gun
200	275	One 2½-inch or two 1½-inch lines
300	240	One 2½-inch or two 1½-inch lines
400	200	One 2½-inch or two 1½-inch lines
500	185	One 2½-inch or two 1½-inch lines
600	Will not supply more than a single 1½-inch line	

HYDRANT-TO-PUMPER LAYOUTS

The misunderstanding of these simple facts causes embarrassing situations at fires (Figure 12.2). The dangers of "in-line" or hydrant-to-pumper layouts should be clearly understood. You cannot get more out of a pumper than is going into it. From the table preceding, it is clear that the allowable distance from hydrant to fire cannot be very great. Yet I have actually seen a fire department attempt to supply two 250-gpm lines from a pumper connected by a single 2½-inch line to a hydrant 300 feet away, which had a static pressure of 60 psi. If the two

Figure 12.2. *Misunderstanding of fire service hydraulics or a lack of knowledge or skill on the part of a pump operator can lead to embarrassing situations.*

lines were supplied the required gpm, the friction loss would have been 165 psi between the hydrant and the pumper. How could a 60-psi hydrant pressure overcome this? The pump operator's reaction was to increase engine speed to a point at which the pump was cavitating and still delivering only about half the water the nozzles required, and at a nozzle pressure of about 15 psi. Here we had the unhappy sight of a fire department equipped with modern apparatus and a fairly good water supply in a useless situation. The building burned down in front of them because they couldn't fathom what was wrong.

Unfortunately, this example is not an isolated instance. I have seen others like it, including a case where a fire department put a 200-gpm portable pump drafting from a creek to supply a 750-gpm pumper 200 feet away. The chief could not understand why the pumper could not deliver its rated capacity.

To some readers these cases may seem unbelievable, but to others they are actual experiences. I could disclose a few dozen more, but they would only tend to emphasize two weaknesses: One is the woeful lack of understanding of fire stream hydraulics; the other is that our water measurement technology is lagging. In this day, we are still depending on pressure readings and hydraulic calculations to enable the pump operator to determine flow. No calculations would be needed if there was a flow meter attached to a pump outlet.

GPM vs BTU

T It is quantity in gpm that determines the extinguishment of a fire—not pressure. If the pump operator knew the capacity of the nozzle and the amount of water flowing, he would not have to know the length of the hose line, or whether the nozzle was above or below ground, to figure the correct pump pressure. If the flow registered at the discharge gate of the pumper was that suggested for the nozzle, the flow at the nozzle would be the same, and no calculations of length of hose line or height of nozzle would be necessary.

As a fire service educator, and one who has taught hydraulics, I suggest we forget pounds per square inch and use only gallons per minute in measuring fire streams. This simplification is certainly within the reach of present-day instrument technology; it would greatly reduce error and improve efficiency in the application of water.

HOSE OPERATIONS

There are two broad categories of fire hose:

1. Attack hose
2. Supply hose

In the 1800s—for reasons now obscure—a diameter of 2½ inches became the standard size of fire hose. There was no other size except the ¾-inch hose on "chemical" (soda and acid) engines then in vogue.

In the early 1900s, a smaller diameter, 1½ inches, was introduced. Fire departments were cautious about its limitations, so for quite a while it was used only on brush and trash fires and for overhaul. Then it was found to be effective on minor structural fires, and it increased in popularity until, by the 1940s, it became the most frequently used size.

Also, early in the twentieth century, some departments started using lines of 3-inch and 3½-inch diameter, between the pumper and the 2½-inch attack line. But, until 1970, other hose diameters were virtually unknown in North America, although a very few departments did have other sizes.

Then, in the early seventies, we were introduced to 1¾-inch attack lines and large-diameter (4-inch and 5-inch) supply hose. New York City adopted 1¾-inch hose to go with their newly developed "rapid water" system, because with the rapid water additive reducing friction loss, 1¾-inch hose could deliver the same gpm as 2½-inch. The rapid water was later abandoned, but the 1¾-inch hose was retained.

Other fire departments tried the 1¾-inch hose with plain water and decided to use it instead of 1½-inch, some feeling that it would also replace 2½-inch. Then others said 2-inch hose is an even better compromise. Now we have varying preferences as to the best size of "small-diameter" attack lines. Let us compare them to each other and to the old standard 2½-inch hose.

For interior firefighting, we shall assume that, because of nozzle reaction and hose mobility, a two-person nozzle team can handle up to 200 gpm safely. Without exceeding 250 psi pump pressure, and allowing 100 psi for nozzle pressure, we have an amount of 150 psi left for friction loss and elevation loss. Ignoring the elevation loss, we find that the friction limits the length of the hose stretch as follows (with a 200 gpm flow):

2½-inch hose:	1,500 feet
2-inch hose:	500 feet
1¾-inch hose:	300 feet
1½-inch hose:	100 feet

Other factors to be considered are the weight of the hose line, both empty and charged, and the nozzle reaction, which will vary with both flow and pressure. Naturally, the larger the diameter, the more the hose will weigh empty, and the more water it will hold—and water is heavy.

If a smoothbore nozzle is used instead of a fog nozzle, we would be able to use lower nozzle pressures and use the pressure saved for overcoming elevation loss or for longer stretches.

We took the flow of 200 gpm in the above example because it is the most usual flow when 2½-inch hose is used. (Of course, the fog nozzles are rated higher, but in actual practice are not often used at maximum rating in interior firefighting.) This flow is also obtainable from a 1-inch tip at 45 psi nozzle pressure. Undoubtedly, most nozzle teams would prefer the more easily handled flow of about 175 gpm, which 1¾-inch and 2-inch hose can provide with ease. Friction loss per 100 feet of hose at 175 gpm is shown below with weight of water.

Hose Size	*Friction Loss*	*Water Weight (per foot)*
2½-inch	8 psi	2.13 pounds
2-inch	23 psi	1.35 pounds
1¾-inch	34 psi	1.04 pounds
1½-inch	95 psi	.77 pound

Many fire chiefs feel that the increased mobility of the small-diameter hose offsets the sacrifice of higher flow. It is also said that flows of about 175 gpm are adequate for the vast majority of fires. The Royer-Nelson formula shows that 175 gpm is right for 17,500 cubic feet of fire (a fully involved house or store).

Just as there is no universal golf club good for every shot, there is no universal hose size good for every fire. The right size of hose is the one that will meet the needs of the department most frequently, provided that, if it isn't adequate for the occasional major fire, there is larger hose available. (There is not much sense in having a 1,250 gpm pumper and not being able to apply more than 700 gpm from it.)

Both volunteer and paid departments are responding with less company strength than in the days when a small line was automatically backed up by a larger one. Today, the first-in engine company will not usually have that capability, so the first choice must be adequate.

LARGE-DIAMETER HOSE

Large-diameter hose (more than 3 inches) was developed in Europe during World War II, to compensate for water mains burst by aerial bombs. It was generally ignored in the U.S. until the early 1970s; then suddenly it gained wide acceptance. It can be used in three ways: as a supply line from a hydrant to a pumper near the fire (its most popular use); as a supply line from a pumper to a manifold which will supply several smaller lines; and as a relay line between pumpers when the distance from the water supply to the fire is great, and large amounts of water are needed.

The hose came from Europe and so did its couplings. They are known as Storz couplings and are of the quick-connect, "sexless" type, meaning they are unthreaded, with no male or female end.

This hose is most frequently used as a supply line from hydrant to fire. The popular sizes are 4-inch and 5-inch diameter, although 6-inch is also available. The choice among them depends upon what the hose is to be used for, the hydrant pressure available, and the spacing between hydrants.

When the water is being supplied by a pumper, the chief limitation is the capacity of the pumper. If it is a supply line from a hydrant to a pumper, the flow is limited by the capacity and pressure of the hydrant.

In the first example, if the pumper is delivering 1,000 gpm at 150 psi, the 4-inch hose will carry it up to 200 feet to give a pressure of 125 psi at a manifold for distribution to attack hose lines. The 5-inch hose would do the same over a distance of 600 feet.

If the supply line is hydrant-to-pumper, a 40 psi hydrant pressure would give a 10 psi inlet pressure at the pump for the flows and distances given below:

gpm	*4-inch Hose*	*5-inch Hose*
1,000	150 feet	400 feet
1,250	100 feet	250 feet
1,500	50 feet	200 feet

In a relay—if enough such hose is available—a 1,000 gpm pumper working at capacity (150 psi) would give an inlet pressure of 10 psi to the next pumper at a maximum distance of:

gpm	*4-inch Hose*	*5-inch Hose*
1,000	700 feet	2,000 feet

The hose itself is not very heavy. The 4-inch weighs about 95 pounds per 100-foot length, including couplings. The 5-inch weighs 110 pounds. Water is heavy, however, so a fully charged 4-inch line contains 544 pounds of water, and 5-inch holds 852 pounds in a 100-foot length. Neither can be moved easily when charged, and this problem is a serious consideration before charging the hose.

There have been several cases of damage to large hose when cars were driven over a charged line. In some instances, the undercarriage of the car cut or abraded the hose. A burst in the major—or only—supply line can have serious consequences at a fire. This kind of damage, and the need to move the line, can be lessened if it is laid on the same side of the street as the hydrant.

Some departments carry their large hose on reels. Others load it flat in hose beds. When the hose is laid out, twists should be avoided or removed before charging the line because, as the twisted hose turns upon being charged, a small turn might open a coupling. Speeds over 15 mph should be avoided and care taken on turns as the hose is laid. (A woman standing on a sidewalk received serious head injuries when she was struck by a large-diameter coupling.)

HYDRANT SELECTION

In selecting a hydrant that is close to a fire, the pump operator must consider the consequences of the apparatus being threatened by an increase in the size of the fire. If the pumper is moved suddenly or abandoned completely, the firefighters handling the hose lines supplied by it may be seriously endangered. Therefore, the nearest hydrant may not be the best. Another consideration is the danger of

SIZE-UP
CONTINUOUS

the pumper being struck, or perhaps buried, by a falling wall. In cases where there is some likelihood of the fire reaching such a point, it would be better to use a hydrant at a safer (even if somewhat distant) location. If a pumper is already using a hydrant, and the fire progress indicates an increasing danger to it; the pumper should be moved while there is still time to reposition both pumper and hose lines in an orderly fashion, with minimum downtime for the water used by those lines.

The locations of other pumpers already in operation are other important considerations in hydrant selection. It is not unusual to find mains that can supply only one large pumper (at capacity) between cross-connections, or, in other words, in one city block. If another pumper is placed on the same six-inch or smaller main, the friction loss in the main may become so great that neither pumper will get the amount of water it needs. The results vary with the condition (usually determined by age) of the main, the distance from cross-connections, and the sizes of the connecting mains.

LINES TAKEN FROM A PUMPER

There is another item of consideration which can be debated. Should all of the first three or four hose lines be taken from the same pumper if it (and the hydrant) is capable of supplying them? The advantages of this practice include shorter hose lines and quicker stretches. The big disadvantage is in having "all the eggs in one basket," should the pumper break down. Many fire departments gamble on this event not happening and frequently have all the hose lines at the fire connected to one pumper. Other fire departments require that the second line be taken from a different pumper. Some go so far as to require that the first three lines be from different pumpers. Of the various systems, the choice may have to depend upon circumstances, with such influencing factors as the distance between hydrants and the consequences of pump failure.

There are some options to consider when connecting a pumper to a hydrant. For many years, it was the general practice to connect the pumper to the hydrant by the same hard suction that was used for drafting. It was thought that this technique would assure a better water supply in borderline cases where the pumper might not be getting enough water and would start to pull a vacuum. In such a case, it was believed, a soft "sleeve" would collapse, but the hard one would allow the pumper to get more water.

Actually, the only way the hard sleeve would enable the pumper to get more water at vacuum would be by drafting from the hydrant and consequently the system of which it is part, including the water pipes in nearby buildings. There have been cases reported of damage to pipes and mains from this cause. But this problem is a remote chance, and the principal consideration should be whether or not the hard suction is a more efficient means of connecting a pumper to a hydrant than the soft suction or sleeve. (The term "soft suction" is a commonly used misnomer. If it is soft, it can't take suction. "Hydrant connection" is a better term.)

Is there any advantage to be gained by using hard suction to connect to a hydrant? In 1958, the Division of Fire Fighting Equipment of the New York City Fire Department ran a series of tests to get an accurate answer to the question. Among other things, it was found that increasing engine speed to where the pumper was pulling a vacuum of 30 inches on the 4½-inch hard suction gave only a 5 percent increase over the flow at zero intake pressure, or, to quote the report, "Thus an average gain of only 35 gpm per pumper resulted from working in this unusual and dangerous manner. At this point the water was highly discolored due to the excessive velocity of flow through the main."

When the two pumpers used in the tests were working together from one hydrant to which each was connected by a 10-foot-long 4½-inch hard suction, their maximum output was 1,321 gpm. When the same pumpers were working from the same hydrant, but each connected by a 12-foot long, 4½-inch soft hydrant connection, the flow was 1,286 gpm at zero intake pressure—a reduction of only 35 gpm. After that, the pumps were accelerated until a maximum vacuum of 25 inches was obtained, and, although there was some softening of the hydrant sleeves near the pump inlets, there was no collapse, but there was also no gain in discharge. Therefore, it can be seen that the bulky, heavy, hard-to-handle suctions give no practical advantage over the soft sleeve, which is much easier to handle.

Pump operators should be taught not to operate pumps at a vacuum when connected to a hydrant. As can be inferred from the above test data, there will be no significant increase in flow. Furthermore, there is a great chance of harm.

Pump operators should also be instructed in how to guard against overtaxing a hydrant by taking too many lines from the pumper. There are a couple of formulas which enable the pump operator to tell how much discharge capability is left in a hydrant. For instance, if the drop in residual pressure is less than 10 percent when the first fire hose line is opened, the hydrant should be able to supply three times that amount of water. If the drop is between 10 and 20 percent, the hydrant should flow twice as much. With a drop between 20 and 25 percent, it should flow an equal amount. A drop of over 25 percent, however, indicates a flow of less than an amount equal to the first line and is considered too risky for another line.

Some fire departments have to use hydrants with no outlets other than 2½-inch diameter. Many of these departments make a twin hookup by attaching short lengths (about 20 feet long, usually) of 2½-inch hose to each outlet and to a two-way gate on the suction inlet of the pumper. They would be able to get much more water if they used a 12-foot-long, 4½-inch soft hydrant connection with a 4½- by 2½-inch swivel reducer. The friction loss in the two 2½-inch lines is far greater—about five times as much—than in the single soft sleeve with the reducing swivel attached.

RESTRICTED INLET FLOW

Each inlet on a pumper will not necessarily permit the same flow. Some pumpers are equipped with gated 2½-inch inlets, which are connected by piping and elbows to the suction side of the pump. In many of them, the friction loss in the piping is great enough to cut the flow to half of what it would be with direct entrance to the pump. The same holds true, to some extent, of front or rear suction inlets. Sometimes a 4½- or 5-inch inlet is attached to a pipe of much smaller diameter, which has sharp bends. It is not uncommon to find that a pumper which can draft 1,000 gpm from a direct inlet to the pump has difficulty getting over 700 gpm from a front or rear inlet. For similar reasons, some 2,000-gpm pumpers have to be fed through two inlets simultaneously to reach capacity.

When pumpers are operated from draft, the task is complicated by two factors. One is that an air leak can affect the efficiency of the "prime" within the pump and suction hose that is necessary to bring the water up into the pump. The second is that with centrifugal pumps, which are the type most widely used, a device must be engaged to eliminate air from the pump and bring about the reduction in air pressure required there.

Sometimes this suction-creating device can fail, and the pump won't draft. There are two types of immediate action which can overcome this difficulty. Another pumper, or even a portable pump which can draft, can be connected to a discharge gate of the disabled pumper. The priming device on the second pumper then removes the air from the first pump until water reaches its pumping chamber. When it does, the second pumper is shut down because the first pumper can then maintain suction as long as it doesn't shut down (Figure 12.3). The second pumper can then be used elsewhere.

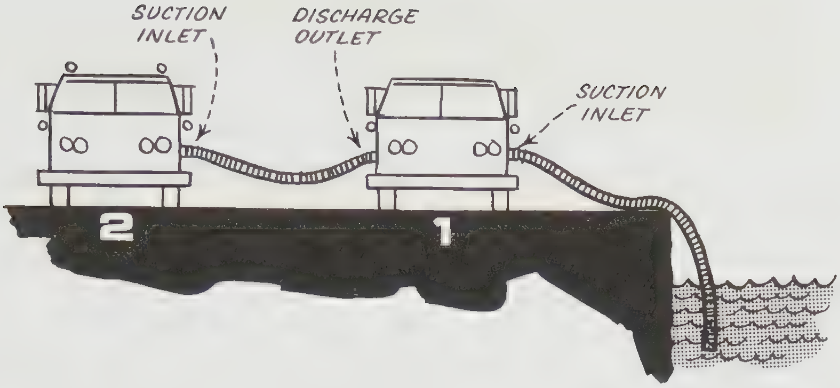


Figure 12.3. *When pumper 1 is unable to draft water because of a defective priming device, pumper 2, using its priming device, can exhaust the air from pumper 1 as indicated. When water fills pumper 1, pumper 2 can be disconnected and pumper 1 will continue to draft, providing it doesn't shut down.*

Another method can be used when there is no other pump to assist as just described. It calls for the use of an improvised foot valve in which a siamese connection (with clapper valves) is attached to the outboard end of a suction hose that is connected to a pump inlet. Water from the vehicle's tank (or other source) is then flowed into the pump, and consequently the suction hose, until both are full. One of the clapper valves must be held open while doing this to permit expulsion of air from the suction hose. The suction hose is then lowered into the water from which it is to draft and the pump engaged. As the water is drawn up from within the suction hose, the clapper valves will open and permit the outside water to enter.

No mention of drafting is complete without a warning that the source should be checked to ascertain that the liquid about to be drafted is water. This warning may seem overstated, but there is a documented case of a fire department taking suction from a pool of asphalt! To make matters worse, the pumper supplied a sprinkler system, and by the time the liquid asphalt solidified, it had reached the second floor of the building. The sprinkler piping had to be replaced, and the pumper went back to the factory for a unique type of overhaul.

DELIVERING THE WATER

The second phase of engine company work is to get the water from the source to the nozzle, which can be done in three basic ways:

1. Place the pumper at the source of water.
2. Place the pumper at the fire.
3. Place one pumper at a source which pumps to another pumper at the fire.

It is obvious that method number 2 could not be used from draft, but only from a hydrant. The other methods (numbers 1 and 3) could be used from a draft or a hydrant. Let us compare the merits of all three when a hydrant is used.

The advantage of having a pumper at the hydrant is that it can put out its rated capacity, assuming adequate supply, which is of growing importance as our pumpers increase in size. Years ago, pumpers were seldom of a capacity larger than 1,000 gpm. Now, 1,250- and even 1,500-gpm pumpers are becoming more widely used. There is not much sense in buying pumpers of such capacity unless they can be used at the water source. When the pumper is at the hydrant, additional hose lines can be taken from it until its capacity is reached.

There is some disadvantage to having the pumper at the hydrant. All the tools, ladders, and breathing apparatus needed from it will have to be brought to the fire. This handicap can be overcome by stretching from the hydrant to the fire. Here, tools, ladders, and masks are at hand ready for use. But this (hydrant-to-fire) stretch in turn creates other handicaps. One is that the pumper will be held to a limited percentage of its rated capacity, depending on its distance from the hydrant, as explained earlier. Another is that one firefighter will have to remain at the hydrant until it can be opened.

If fireground conditions are favorable, and tools can be supplied by other units, a stretch can be quickly made from fire to hydrant, which assures a good supply of water to the fire (several streams if necessary), with only one firefighter tending the hydrant and the pump.

The third method, using one pumper at the source and another at the fire, descends from the "wagon and pumper" combination and is the oldest method of all. In the days of steam and horses, pumpers carried no hose. All the hose was carried on another vehicle called a hose wagon, hose tender, or hose cart. Customarily, the pumper stopped at the hydrant, the wagon pulled up alongside the pumper and dropped the female end of its hose load. Then the wagon was driven to the fire, laying hose as it went. After the steam and horses were replaced by gasoline-driven pumpers, the hose wagon and pumper were combined on one apparatus, but for many years the grading schedule of the National Board of Fire Underwriters recommended that every third engine company in high-value districts be equipped with both a pumper and a separate hose wagon. Some fire departments kept the wagon in every company. Later, some of these departments began using pumpers as hose wagons. At first, these were actually hose wagons with small pumps, but eventually they were replaced with full-size pumpers.

This design is undoubtedly the most flexible arrangement for delivering water, but it is certainly not the most economical. It not only requires double the equipment, thus increasing purchase and maintenance costs, but it doubles the highway accident probability as well. And to be used most effectively, it requires additional personnel. In effect, it is a short-distance relay.

One manner in which the two-pumper combination is used is for the "wagon" to lay a line to the fire from the pumper at the hydrant. This line is put into the suction side of the wagon,which then pumps water to the nozzle. If additional lines are taken from the wagon, other lines might have to be stretched between it and the pumper at the hydrant. Large-diameter supply lines from the supplying pumper can reduce or eliminate the need for additional supply lines.

Use of Attack Pumper

Lately the so-called "attack pumper" concept has been growing in popularity. Here, the first-arriving pumper goes straight to the fire without stopping at a hydrant. It starts the attack with a preconnected hose line that uses the water in its booster tank and is undoubtedly the quickest way to get water on a fire with the fewest personnel. This type of attack (using a 500-gallon tank) will suffice for nine out of ten fires; however, two items must be considered. One is that provision must be made for a continuous supply of water if the tank runs out before the fire is out. The other is what alternatives you have if the preconnect line is not long enough to reach or large enough to extinguish the fire.

Use of Manifolds

In recent years, there has been an increase in the use of hose manifolds, which was made possible by the advent of large-diameter hose. These devices are far from new (Seattle and Philadelphia have used them for years). A manifold, placed near the fire and connected to a pumper at a hydrant by large-diameter hose, can make that pumper's capacity available to several 2½-inch lines stretched from the manifold to the fire. The saving in labor and friction loss over stretching lines from the pumper to the fire is considerable. Another advantage of the manifold is obviously less "spaghetti" cluttering the fireground. The leading disadvantage entails the consequences of a burst in the large supply line, knocking several hand lines out of commission simultaneously.

As the use of large-diameter hose and large-capacity pumpers becomes more widespread, we can expect to see larger manifolds. It is already within the realm of possibility for a single pumper to supply five 2½-inch outlets on a manifold with 250 gpm each.

No matter what method is chosen to deliver water from a pumper at the water source to the nozzles that are to apply it to the fire, there are certain basic principles that the engine company officer should bear in bind.

When hose larger than 2½-inch is carried, it should be used whenever practicable, but for ease in handling, that portion of the stretch to be taken inside a building should be reduced to a 2½-inch or smaller line.

Hose Practices

When sprinkler or standpipe systems are present, one of the first lines should go into the sprinkler siamese. If the fire is on the fifth or higher floor, the first line should go into the standpipe siamese to provide adequate pressure in the system.

When ten or more lengths of 2½-inch hose are stretched, a siamese connection should be placed between the third and fourth lengths from the nozzle so that an additional line can be put in later if the flow in the single line is insufficient. This arrangement still leaves 150 feet of a single line behind the nozzle for maneuverability and advance into the building.

In a case where the siamese was omitted and the need for the second parallel line becomes apparent, there is still a means of overcoming the deficiency. Stretch a second line parallel to the first. Put the siamese in the second line, start water in the second line, shut down the first line and after putting it into the other side of the siamese, start water in it again.

When deciding how much hose is going to be needed, it is always better to stretch too much rather than too little. "Stretching short" is a frustrating experience. On the other hand, surplus hose creates problems that can be avoided by training and experience. A long-standing rule of thumb has been that from the front door of the building there should be one 50-foot length of hose for each floor up to the fire floor, plus one extra. For example, if the fire is on the fourth floor, it would call for five lengths from the entrance. This rule usually gives enough hose to reach all parts of the fire floor, but if the building is large (over 100 feet in either width or length), it would be well to add another length.

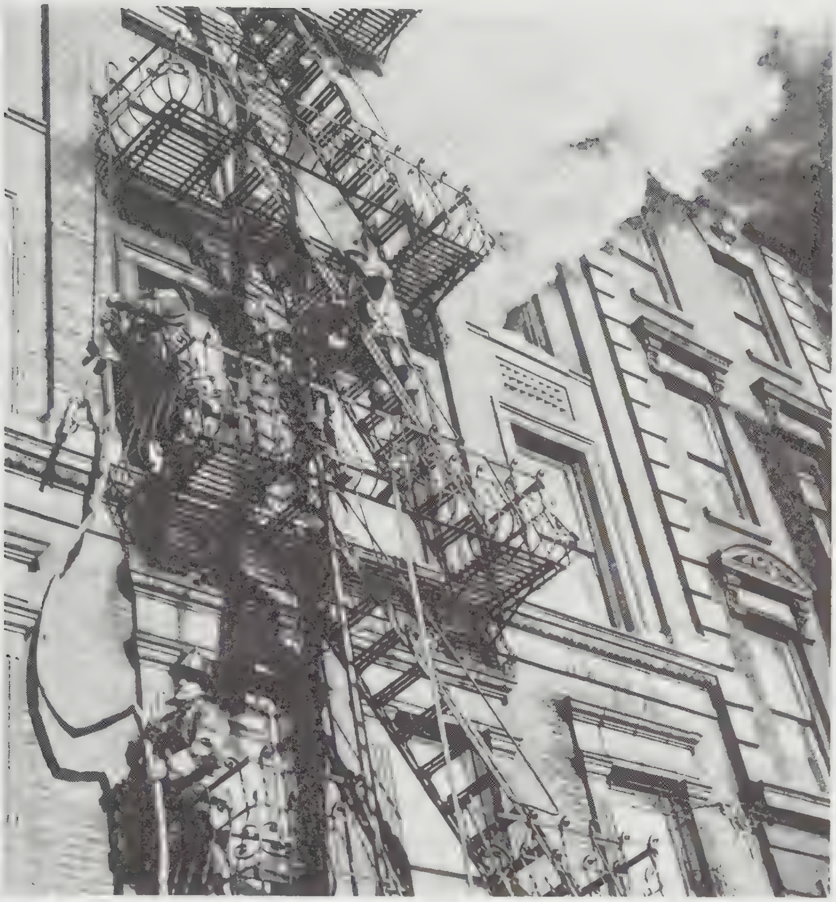


Figure 12.4. *Often hose lines other than the first should be taken up the outside of a building. The fire escape stretch that uses a hook provides the fastest way to reach upper floors.*

Hose lines, other than the first, should be taken up the outside of the building by fire escape, aerial ladder, or rope whenever practicable. The fire escape stretch, using a hook, is the fastest way to get hose to the upper portions of a building (see Figure 12.4).

When hose is to be hoisted by rope, a hose roller should be used to protect the hose from abrasion, as well as to make the hoisting easier by reducing the energy lost in friction as the hose is dragged over a cornice or window sill.

Hose straps should be attached whenever the unsupported vertical distance in a hose line is over 30 feet. This device relieves the strain on couplings caused by the weight of the water and the hose containing it. A common practice is to attach hose straps to banisters (or fire escape balconies, as the case may be) at alternate floor levels.

This idea brings up the question of firefighters carrying hose straps and spanners. They aren't large or heavy and can be easily carried. Furthermore, it is sometimes a long way back to the pumper to get one when it is urgently needed. Each firefighter should be equipped with both and they should be carried on his or her person. An otherwise professional-looking job can be spoiled by a leaking coupling which continues to leak for lack of a spanner.

When hose is being stretched within a building, care should be taken to assure that the uncharged line doesn't go under a partly opened door or that the door doesn't close on the empty line. Otherwise, when the line becomes charged, the door will prove to be a highly efficient hose clamp, which usually can be removed only by taking it off its hinges.

Identification of Lines

It is surprising that hose tags are not more widely used. A simple tag system employed in some departments enables ready identification of each line. There are two tags in a set (one for the nozzle, the other for the pump outlet supplying it) that contain the engine company number and a numeral to identify the line. The first line from Engine 99, for example, would be tagged with that company's number 1 tags, the second with the number 2 set, and so on. Thus, any communication by radio or otherwise can refer directly to the proper line without confusion or the need for tracing it back to the pumper. While tags are not much needed at small fires, their aid is invaluable at larger fires. It is a good idea to use them at all fires for two reasons: One is that a small fire may become a large one; the second reason is to encourage their use and make it habitual so that, when they are really needed, they will be there.

Years ago, most cities adopted ordinances to prohibit vehicles from being driven over hose. In those days, all vehicles were horse-drawn and had iron tires. Now, with pneumatic rubber tires in universal use, the likelihood of the hose being damaged by vehicles is limited; in fact, experiments in Detroit in 1967 showed that 40-ton army tanks could ride over hose lines without causing damage. There are three definite hazards, however, which should be avoided. The first two involve couplings. If a vehicle with dual wheels drives over a coupling, the coupling can become caught between the dual tires; the hose then winds around the wheel until it is torn apart somewhere. Men have been hurt by this mishap. Even when dual wheels aren't present, driving over couplings should be avoided because they can be bent by a heavy vehicle. The third hazard to be avoided is stopping a vehicle with a wheel on the hose line, thus cutting off water as though a hose clamp had been applied.

Strange as it may seem, these incidents still occur all too frequently. The reasons are obvious: excitement and haste. A person becomes so intent on doing what he is supposed to do as quickly as possible that he neglects to notice any side effects of his actions.

This book does not delve into the subject of hydraulics, which has been covered more than amply by Casey's *Fire Service Hydraulics* and other texts. Yet any discussion on the use of hose lines must point out the need for an understanding of required flow if hose is to be used effectively within the scope of our present technology. A disappointing sight at many large fires is a weak stream that is caused not by inadequate water supply, but by lack of a pump operator's knowledge or skill.

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Choice of Hose to Stretch

At most fires, the officer of the first engine company to arrive has a choice of three hose sizes with which to make the initial attack. One of the most common failures involves the selection of hose that is too small to meet the fire needs; it is also a mistake that can have disastrous consequences. What became one of the worst conflagrations in United States history was estimated to be a "booster line job" when the first engine company arrived. By the time they got the line stretched to the fire (in the basement of a large mercantile building), the fire proved to be too much for the small line. The company was driven out of the building, and the rest is history.

It is because of incidents like this that some departments have set rules limiting the use of small-diameter hose. There is no doubt that the lighter weight and easier handling qualities of small-diameter hose make it popular, especially when personnel are not plentiful. Years ago, it was axiomatic to back up a small initial attack line with one of larger diameter, which provided a quick attack and ample volume in reserve. Thus a booster was backed up by a 1½-inch line, and a 1½-inch line was followed by a 2½-inch line; this procedure is an excellent practice when personnel are available to carry it out, but when there are not enough firefighters for back-up lines, a judgment must be made. Once again we refer to the Royer-Nelson formula as a means of determining nozzle size and hose diameter, with the further admonition that it is better to have too much than too little.

INTERIOR FIREFIGHTING

Whenever firefighting can be conducted inside the fire building, it should not only be encouraged but demanded. In the United States, and also abroad, the distinction between a good fire department and a poor one is based on whether or not they "get in" when the going is rough. This distinction is not based on pride alone; it has its real basis in efficiency.

To ensure maximum effectiveness in operations at a fire within a building, it is essential that members of the firefighting force enter the building immediately and execute the attack from within. This task must be done, not only to find and remove trapped or unconscious occupants, but to extinguish the fire promptly. Many fires are lost because of failure by firefighters to enter quickly. For water to extinguish fire, it must come into contact with the burning material. In many cases, this contact can be made only from the interior, and in most cases it is done more effectively from the interior.

Interior attack may involve discomfort, and frequently a degree of risk, but these problems are more than compensated for by rapid extinguishment of a fire, as well as less resulting water and fire damage. Some of the hazards can be guarded against by the use of proper protective breathing equipment and clothing, others by deliberate, careful actions.

The points at which firefighters should enter a fire building are determined by two principal factors: location of the fire and purpose of entry. Entry for the purpose of search can be made through whatever doors or windows are most suitable, and the same is true of ventilation. Entry with hose lines should, however, be made with the objective of cutting off fire travel, rather than following it. Doorways are preferable to windows as points of easy and quick entry—and retreat, if this action becomes necessary.

The first hose line is usually taken through a doorway selected to allow the nozzle operators to reach the fire with the least difficulty, provided this placement will not put them in the position of pushing the fire ahead of them. As I said before, the primary rule of firefighting strategy is to locate, confine, and extinguish the fire. Therefore, the first nozzle or nozzles should be brought in at a point that is most vulnerable to the extension of fire, in an attempt to cut the fire off and push it back.

Stairways, particularly, should be protected to prevent upward travel of fire. There is an old axiom, "Save the stairway and you save the building." Some fire departments require that at basement fires the first line be taken to the first floor at the top of the interior basement stair to prevent upward extension of the fire.

The point of entry for additional hose lines must be selected so that they may work in harmony with the first line. Hose streams create strong air currents that move in the same direction as the stream, tending to push heat and smoke ahead. It can therefore be harmful to have hose streams working toward each other from opposite directions, since each tends to retard the advance of the other.

It is particularly undesirable to direct an exterior stream into a building where firefighters are already operating. This practice has the effect of nullifying ventilation and pushing heat and smoke to the interior, often injuring the firefighters inside or forcing them to retreat. It is the duty of the chief in charge of a fire to coordinate the attack and prevent subordinate officers or firefighters from directing hose streams in a manner that hinders interior operations or endangers other firefighters.

Necessity for Illumination

Since the other members need both hands to hold and move the hose line, the officer in charge of a group must provide illumination as well as guidance. To do this, he should carry a powerful flashlight or electric lantern. Ladder company members assigned to perform search and ventilation should also carry flashlights.

It is desirable that a member carrying forcible-entry tools accompany the firefighters advancing a hose line so that any locked doors can be readily forced open. This individual can also pull apart burnt materials without the delay caused by the lack of such tools.

The selection of the hose size to be used depends upon the size and type of the fire and the available water supply. Fire in dwellings can usually be handled effectively by 1½-inch lines, but large-area buildings may require streams from 2½-inch lines; however, available water supply may limit the size of hose and nozzles. The important thing is that the officer in charge does not underestimate the fire and begin attack with an insufficient volume of water. Officers and firefighters should know what each nozzle discharges at given pressures and then select the right nozzle for the job.

Entry should be made as soon as possible. For a company advancing a hose line, this means as soon as the line is charged with water. If, however, the fire is above the first floor, they should advance as far as they can before the line is charged, and wait for water at a point near the fire but not where they would be in danger of being cut off by the flames.

The nozzle should not be opened until it is in a position to hit the fire. Streams should not be directed injudiciously at smoke. The alert officer will see to it that the nozzle is advanced to a point where fire can be seen before he gives the command to open the nozzle.

When the nozzle is opened for the first time, a considerable amount of air trapped in the hose line will be pushed out ahead of the water. If the nozzle is aimed at the fire, this air may accelerate the burning. Therefore, the efficient thing to do when opening the nozzle for the first time is to hold it close to, and aim it at the floor, then open it slowly and keep it open until the air is discharged. Then close it, aim it over the fire, and reopen.

A nozzle should not be opened too quickly or the sudden release of pressure may wrest it from control. It should not be closed rapidly because sudden closing may cause water hammer, which may burst the hose line.

If the room is well involved with fire, the nozzle, whether fog or straight stream, should be directed upward when open and rotated rapidly to get the greatest coverage. Straight streams should be directed at the ceiling over a fire so that the water will bounce off the ceiling and come down like rain over a large area. Fog should also be aimed toward the ceiling because the greatest amount of heat is concentrated there. Both types of nozzles give maximum effectiveness if rotated rapidly.

Usually in a hot, smoky atmosphere within a building, the nozzle operator will operate more effectively if he gets down on one knee, aims and opens the nozzle, and moves it as described above until the portion of the fire than can be reached from that point is darkened down. He should then close the nozzle and move quickly, in a crouching position, to the next point from which fire can be seen, and repeat the operation. When he is about to move forward, he should call for "more line," and the firefighters behind him should move the line forward. The nozzle operator should not have to pull the line or otherwise exert himself, and if a 2½-inch line is being used, the individual behind the nozzle operator should take up the strain caused by the nozzle reaction, leaving the nozzle operator free to aim and move the nozzle.

The officer in charge of the hose line should make every attempt to keep it moving forward; a line that does not advance is not being fully utilized. An adequate hose stream will put out all the fire it can reach in a few seconds. If it is not moved, any additional water used from that position is being wasted. The line must be kept moving throughout the building as far as necessary to bring the nozzle to points where the stream darkens the remaining fire.

The officer directing a hose line should not attempt to be a leader in the literal concept of the word. If he gets ahead of the nozzle, he may, at times, obstruct operations. His most practical post is directly behind the nozzle operator to direct him and urge him forward at the right time. He should make sure that the nozzle is being operated properly and that it is not kept open after "darkening down" the fire. He should see to it that the one on the nozzle is relieved frequently, and that the other firefighters relieve each other as conditions require.

Firefighters should not bunch up near the nozzle; they should be spaced at intervals along the hose line. When the line is not being moved, it should be allowed to rest on the floor. When the command, "More line!" is given, the firefighters should then pick up the line and move it forward until ordered to stop. They should stop immediately when ordered because a charged hose line is rigid enough to push the one on the nozzle into danger.

Taking the Hose Up

When the fire is above the ground floor, the empty hose should be taken up the stairs and charged with water after the nozzle is on or near the floor where the fire is located. The reason is obvious: an empty hose line is far lighter and easier to move than a charged line. There is, however, a choice of methods in moving an empty line that deserves serious consideration.

Nationwide, the most popular method is the shoulder carry, whereby each firefighter carries on his shoulder a few folds of hose that unfold as he climbs the stair. This unfolding, or laying out, starts with the last firefighter in line and ends with the first. But this method poses some problems. First, it takes a lot of time back at the pumper to load the hose on each person's shoulder. Second, the hose remains on the stairway, and a charged 2½-inch line presents quite an obstruction to other members on all but extremely wide stairs. Finally, should a 2½-inch line be charged while crew members are still on the stairs, they can be pinned against a wall or caught in other awkward positions.

Another method, not widely used, is to pull the necessary amount of hose to the foot of the stairs and feed it up the stairwell in a fashion similar to the fire escape stretch, with a firefighter on each floor pulling up the hose, while the nozzleholder climbs the stair with a few folds on his shoulder. This method saves the time of loading the hose on every person's shoulder and keeps it off the stairs. When the line is hanging in the stairway for a distance of more than three stories, however, it is desirable to attach it to the banister by hose straps at alternate floors. This practice relieves the strain on the couplings caused by the combined weight of the hose and the water in it.

When the smoke is heavy or the heat intense on the fire floor, the hose crew can usually wait in comfort on the stairs a few feet below until the water reaches the nozzle. In the case of an enclosed stairway, they can even take the hose up the stairs, a half flight or so, for easy advance afterward, as shown later in the chapter on fires in high-rise buildings.

The firefighters wearing breathing apparatus should refrain from drawing on their supply of air until they reach the place where they will need it. The exertion of pulling hose up several flights of stairs can cause the consumption of much of an individual's air supply, which is a waste of valuable breathing time if one is not yet in a toxic atmosphere.

The value of a charged hose line to force entry or effect ventilation should be remembered. When locked doors are encountered, they can be forced open by putting the nozzle against the door at the level of the lock, straightening the hose line, and pushing it against the door. The damage is not great, and the procedure is safe. A straight stream or solid stream at ordinary pressures can break window glass and provide ventilation—a method that is quick and can reach many windows in a short time.

Concealed Fire

The firefighters using interior hose streams will sometimes encounter special situations such as fires between walls. In a balloon-frame dwelling, the line can be taken to the attic and a straight stream directed along the attic walls so that the water will run down between the studs and extinguish the fire coming up between the walls. I should like to add at this point that an experiment that we conducted in Wisconsin using multi-purpose dry chemical in the same fashion was not successful. The reason was that the lightweight particles of powder were carried upward by the thermal currents and could not reach the fire below.

Another method of attacking fires in walls or partitions is to use bent tips or partition nozzles, which are inserted into the wall space through a hole cut for that purpose. In this case, remember that the water directed upward will run down also, so it is only necessary to aim upward. Gravity will bring some water down to the fire below.

Piercing nozzles, having sharp pointed spray tips which will penetrate lath or wallboard, can also be effective on between-the-wall fires, especially on attic or cockloft fires. Some of these nozzles can even by driven through board floors or walls when struck by an ax.

A system using several piercing nozzles in series has been developed in Oklahoma City. When connected by short lengths of hose, this series of nozzles simultaneously provides coverage over an extended area. The system has proven effective when used from the roof above a cockloft fire.

This system raises the point as to the better method of attacking a fire in a cockloft (the space between the ceiling of the top floor and the under side of the roof). At best, a cockloft fire is difficult to extinguish, but it presents a choice of attack—from above or below.

A comparison of each method shows that the attack from below presents the advantage of easier entry. It is easier to put a hole in a ceiling than a roof, and the damage is usually less when the ceiling rather than the roof is pierced; however, the movement of the hose line from point to point is not as easily accomplished as when it is on the roof. It appears then that the approach from below is more advantageous than that from above, but precautions must be taken. The safety of the firefighters operating below the fire may require that a hole be cut in the roof to allow the escape of carbon monoxide before a hole is made in the ceiling which would permit air to enter and cause a backdraft. Such a condition occurred at a store fire, and five firefighters were killed. The symptoms of backdraft described elsewhere in this book are applicable to cockloft fires also and should be guarded against accordingly.

Operating on Stairways

When fire involves a stairway, and the hose stream must extinguish the fire as the line is advanced upward, certain procedures must be followed to assure efficient operations. A straight or solid stream can be directed up a stairwell for an effective distance of 40 to 50 feet. This stream will not extinguish all of the stairway fire, but, if it is of sufficient volume, it will reduce much of the fire's intensity and make the journey up the stairs that much easier.

As soon as the stream directed up the stairwell has accomplished what it can—and this process should take no more than half a minute—the line should be advanced up the stairs. The top of each flight can be considered a crisis point; that is where the heat is banked and where the firefighters tend to stop. If the officer can urge them past this spot to the bottom of the next flight, it will prove much more bearable there. The distance to the ceiling is the crucial factor affecting the heat at the level of the nozzle.

At a stairway fire in a multi-storied building, this process must be repeated at every floor. In a six-story structure, it can be a grueling experience. It helps to shut down the nozzle each time a turn to the next flight is to be made. This shutdown cuts out the nozzle reaction which hinders advance. It is also the time for the officer to push the nozzle operator forward to the bottom of the next flight. If the timing is good, the officer and nozzle operator can lurch forward as soon as the nozzle reaction ceases, and thus make the difficult turn.

The nozzle operator should be relieved at each landing. If the trip is long and the personnel not sufficient, a second turn at the nozzle may be required. It is probably more efficient to have firefighters relieve each other frequently, rather than to push each to the limit of endurance before giving relief.

In this respect, the officer at the fire scene plays a role similar to that of a football or basketball coach during a grueling game. He must be quick to recognize the need for substitution, and act accordingly. The coach can call men off the bench who are well rested. So can the fire chief at a fire of long duration call personnel from other stations or from home. The company officer, however, has a group of limited size and must settle for individual relief on a rotation basis.

Gauging Performance

The company officer directing and supervising the application of water during an interior fire attack should ask himself the following questions:

1. What is the purpose of the water application? Is it a holding action, or is it meant to extinguish the fire completely?
2. How do the actions of my unit affect others? Are other companies applying water on the same story, and perhaps from another direction?
3. Is the water application effective, and, if not, what is the reason?
4. Is the attack progressing the way it should? If not, why?
5. What are the safety hazards to the crew I am supervising?
6. What is the condition of my crew from smoke, heat, and fatigue? In this respect, they should be considered not only as a team, but individually as well. Some may be more in need of relief than others.
7. Is the water damage compatible with the task, or is it becoming more than necessary?
8. Is every member doing a fair share of the work? How well is each performing? There are all sorts of guidelines and gauges for rating employee performance in various other duties, but not for fire duty, the most important one of all. The officer should mentally rate employee performance at a fire by using such criteria as willingness, stamina, effectiveness, and calmness. Where it is a factor, strength should be rated too. Of course, this latter could be argued against, saying that it is favoring an individual because of physical superiority, but superiority of performance is what is being considered. Whether it is influenced by size or strength is beside the point. The same holds true in the selection of professional football players.

The first seven of the above items are also of concern to the chief officer supervising the company in question. In addition, he should also rate their performance as a team and the performance of their officer. Usually, he is not in a good position to rate them individually and often must rate the officer on the basis of the company effort. This practice may be unfair on some occasions but will probably prove to be valid in the long run.

EXTERIOR ATTACK

There are times when interior attack is not advisable because of the peril of structural collapse or because hand-held nozzles cannot provide the required water flow. In such cases, the next tactic is to fall back upon artillery rather than infantry, and resort to the use of master streams.

Ever since the term "master stream" was coined, there has been debate as to just how it should be defined. Some fire departments shy away from the term "master stream" and prefer to say "large-diameter" or "heavy-caliber" stream. Let us put aside semantic differences and accept—even if only for the purposes of this chapter—a common understanding of the term.

It has been generally accepted that the largest stream that can be held safely by hand is one from a 1¼-inch tip discharging about 325 gpm at 50 psi. Therefore, it would be logical to refer to streams of greater flow and pressure as master streams. It can be readily seen that they come in many sizes and that such streams are not usually hand-held.

Fire chiefs have long felt that one large stream is worth several small ones with the same total flow. This situation is not always so, because distribution is important as well as volume, but there are many good arguments in favor or master streams when compared to hand lines.

Safety: Where there is danger of structural collapse or explosion, master streams, because of their longer reach, will permit firefighters to work at safer distances from the fire. In extreme cases, master stream devices can be left unattended.

Conservation of personnel: Usually one firefighter can operate a deck pipe, deluge gun, ladder, or platform pipe. Thus one person can apply more water than six individuals on two hand lines.

Greater penetration: The longer reach of the master stream is valuable at lumber yards and other outdoor storage fires covering large areas. It can also reach the windows of buildings several floors above the nozzle and, at the proper angle, can penetrate far into a building. Furthermore, the master stream has greater wind resistance.

Greater heat absorption: When the master stream strikes the fuel source, its cooling power is proportional to its size (flow rate). Also, a larger portion of it will pass through the flames and hot gases to reach the fuel source.

Reach of Streams

In 1888, John R. Freeman arbitrarily set forth a definition of the effective reach (not total reach) of a solid fire stream which established several qualifications. He then took measurements which showed effective reach distances for different sizes of nozzles at various pressures. It is apparent from his tables that the larger the nozzle diameter, the greater is the reach of the stream. For example, at a nozzle pressure of 50 psi, a stream from a 1-inch tip has an effective horizontal reach of 61 feet, as opposed to the 75-foot reach of a 1½-inch tip at the same pressure. The difference in vertical reach is not so pronounced—73 compared to 79 feet. Furthermore, larger nozzle tips allow larger pressures. Streams from 1-inch and 1⅛-inch tips break up shortly after leaving the nozzle at pressures much over 50 psi, but 1½- and 1¾-inch and larger tips can handle 80 psi nozzle pressure without this problem.

Efficiency of Streams

The application of master streams is an art in which few fire officers have had enough practice at actual fires. It is one thing to drill with such streams and quite another to use them effectively on a fire.

The angle of a stream attacking a structural fire is going to determine how far into the structure a stream of adequate pressure will penetrate (Figure 12.5). Far too often, we see pictures of streams entering a window at an angle that provides only minimum penetration. If the building is 100 feet deep and the stream penetrates only 20 feet, do not expect that it will put out much of the total fire. Yet some chief officers seem to be content to let the building and its contents burn as long as there is an imposing array of streams entering the front windows.

The distance to which a stream will reach through a window is easily calculated. The answer is arrived at by solving a simple geometric problem involving similar triangles.

When the stream enters the second-floor window at a level 10 feet higher than the nozzle, it will strike the ceiling of the second story at a point that varies with the distance of the nozzle from the building. If

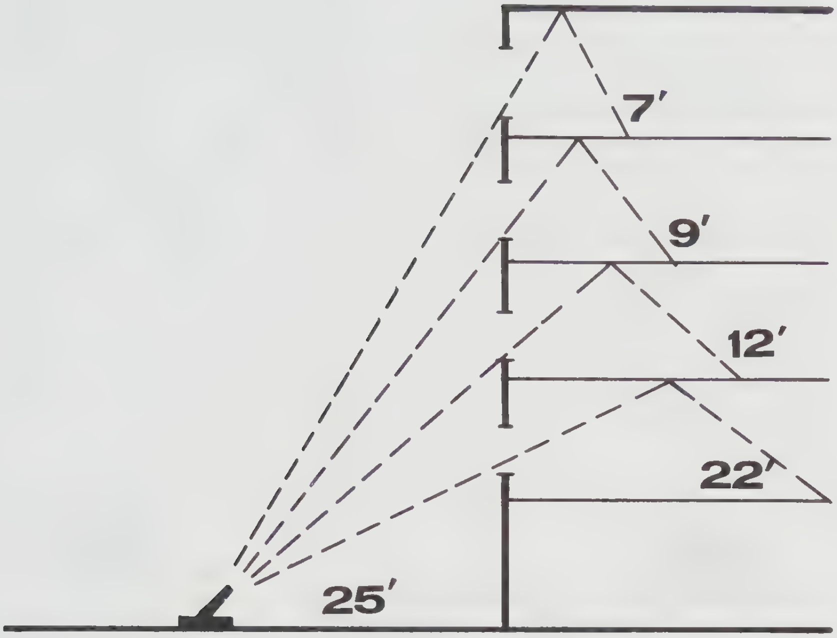


Figure 12.5. *Stream penetration into a building decreases as the angle of the stream increases, as shown here. When the horizontal distance from the nozzle to the wall of the building and the height of the windowsills are known, penetration can be worked out geometrically, using similar triangles.*

the nozzle is 20 feet from the front of the building, the stream will strike the ceiling 14 feet from the front; if the nozzle is 40 feet away, the stream will reach in to hit the ceiling 28 feet from the window, and so on.

We know from experiment that a stream deflects from a smooth ceiling at the same angle at which it strikes it. Therefore, if we double the distance from the front wall to where the stream strikes the ceiling, we can find its maximum reach (at a point level with that which it enters the window). With normal story height, a ratio of 5 to 7 will give the answer of how far the stream can reach into the second floor. But when the stream is directed into a third-floor window, the ratio drops to 5 to 3.5. Thus the penetration of the third floor is about half that of the second floor, and with the nozzle 20 feet from the building front, the penetration would be a maximum of 14 feet. As the angle increases, the penetration decreases to a point at which it becomes obvious that street widths impose serious limitations on the penetration of outside streams from ground level. Even if the nozzle could be placed 60 feet from the building, the maximum fourth-floor penetration would be 14 feet.

Therefore, two precepts emerge. The first is that the angle of stream to ground should be maintained as low as practicable by keeping the nozzle as far as feasible from the fire building. The second

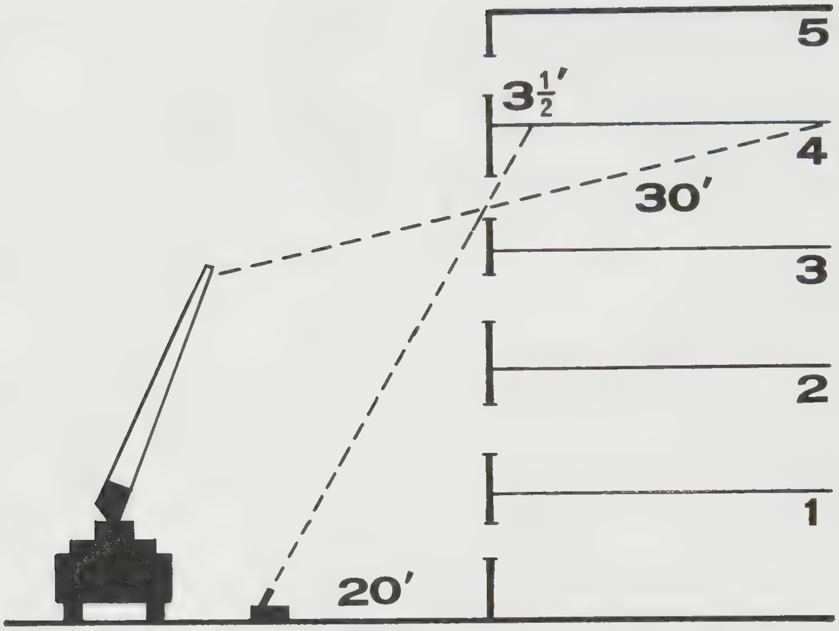


Figure 12.6. The need for elevated streams: A deluge gun on the ground has limited effect on the fourth floor. A ladder pipe is almost ten times more efficient.

is that when adequate penetration cannot be achieved by low-level nozzles, elevated nozzles must be employed.

Elevation of the Nozzles

When streams from ground level or deck pipes cannot provide the required angle for good penetration, the solution is to elevate the nozzle (Figure 12.6). Years ago, water towers provided large-volume elevated streams; today, ladder pipes and elevated platforms have taken their place. The ladder pipe can provide as much as 750 gpm from a fixed location. Elevating platforms can provide that much, or more, with a great deal more flexibility. The platforms can be moved readily from window to window to apply water where needed. Their superiority over the ladder pipe as a means of delivering water is without question.

Naturally the same geometry affecting ground-level streams can be used to estimate the penetration of streams from ladders or elevated platforms. A big advantage of the elevated stream is that the nozzle can be brought close to the window, which not only reduces the angle of penetration but also markedly increases the extinguishing effect.

Operators of an elevated stream should be aware of the ideal angle for the penetration wanted. With ground streams, the angle is often too steep and penetration is minimal. But sometimes we see the reverse of this process when the nozzle of an elevated stream is placed

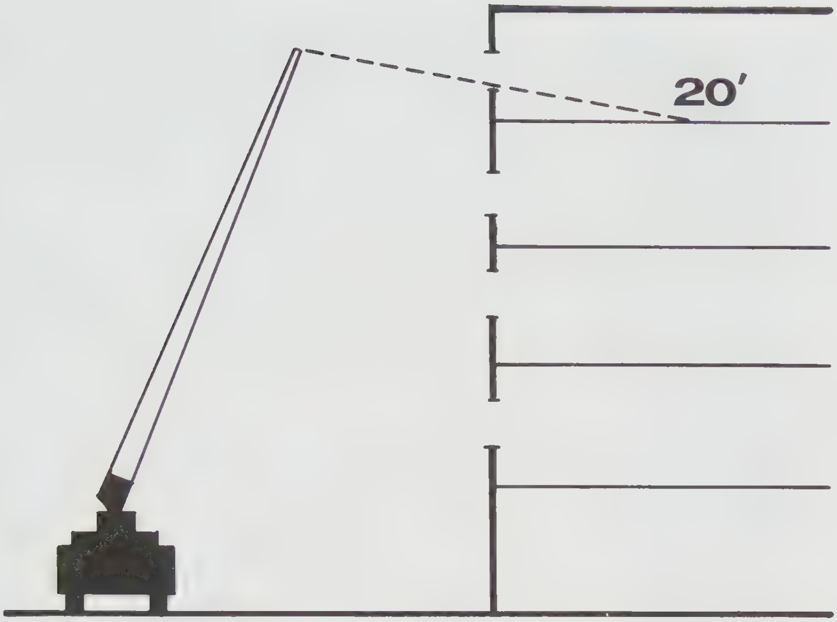


Figure 12.7. When the elevated stream—aerial or platform—is positioned too high, it will have limited effect on the fire.

too high, and the stream is actually aimed downward in order to get it in the window. Such a stream will not extinguish much fire (Figure 12.7). The nozzle, when ideally placed, should be just inside the window, aimed to strike the ceiling first near the window, and then gradually farther back. When the nozzle cannot be placed through the window opening, it should be as close to it as possible and slightly below the sill, so that the stream is deflected off the ceiling for maximum reach and effect.

Fog nozzles are not very effective until actually introduced into the building. The effect of a fog stream decreases with the square of the nozzle's distance from the window at which it is aimed. Ladder and platform pipes allow the fog nozzle to be inserted into the window opening for maximum efficiency.

A mistake that is frequently made is to use nozzles too large for elevated streams, which experience more pressure losses by far than ground-level deck-pipe streams. A ladder pipe discharging 750 gpm would have the following losses if it were elevated to a height of 65 feet:

Loss due to elevation	28 psi
Loss in 100 feet of 3-inch hose	45 psi
Total losses on ladder	73 psi

This total is merely the increase in pressure loss over a deluge gun at ground level. If nozzle pressure is added, we can quickly see that the pressure required at the base of the ladder is beyond the capability of a 1,000-gpm pumper, unless it is virtually at the foot of the ladder. To pursue the matter further, we can take actual examples.

A fog nozzle at 100 psi, flowing 750 gpm, would require a base pressure (at the foot of the ladder to supply the pipe through 100 feet of three-inch hose) of 173 psi.

A 1¾-inch tip would require a ladder base pressure of 140 psi to provide a nozzle pressure of 67 psi in order to deliver the same flow.

Thus, it can be seen that the fog nozzle requires the pumper to be no more than 50 feet from the base of the ladder, and the 1¾-inch tip requires that the pumper be within 100 feet, to provide the same flow (750 gpm) if three-inch hose is used.

Usually the 1½-inch tip or the 500-gpm fog nozzle is adequate for elevated streams and will allow greater distances between the pumper and the base of the ladder or platform. For instance, at a height of 65 feet, the 500-gpm fog nozzle can be supplied using three-inch hose all the way, from a 1,000-gpm pumper 200 feet distant. The 1½-inch tip at the same flow would allow a 400-foot separation.

It is quite apparent that a single 2½-inch hose line is not adequate for supplying master streams, whether they be elevated or at ground level; it should not be expected to provide more than it can. The same is true of the pumper supplying the master stream. The gpm-pressure ratio of the pump must equate with the stream requirements or else another pumper must be added to meet the need.

Directing a master stream often requires the positioning of one firefighter, remote from the nozzle, to direct the firefighter controlling the nozzle. The person at the nozzle has a very limited view, which is often obstructed by the stream itself. Another individual with a side view from about 30 feet away can better judge if the stream is striking its target or not, and direct the nozzle accordingly (Figure 12.8).

When smoke is so thick that it obscures the face of a building, there are two ways to tell if the stream is entering windows or striking the wall. The sound is quite different when the stream strikes the wall than that when it is passing through a window. Officers should learn to note the difference. Also, when the stream is striking the wall, the water will run down the wall and can be easily detected at the bottom of the wall.

If the water is getting through the windows, much of the excess will run down the stairs and be quite noticeable at the foot of the stairway. If it is warm, it indicates that the water has been absorbing heat. If it is cold, it indicates that it probably did not reach the fire.

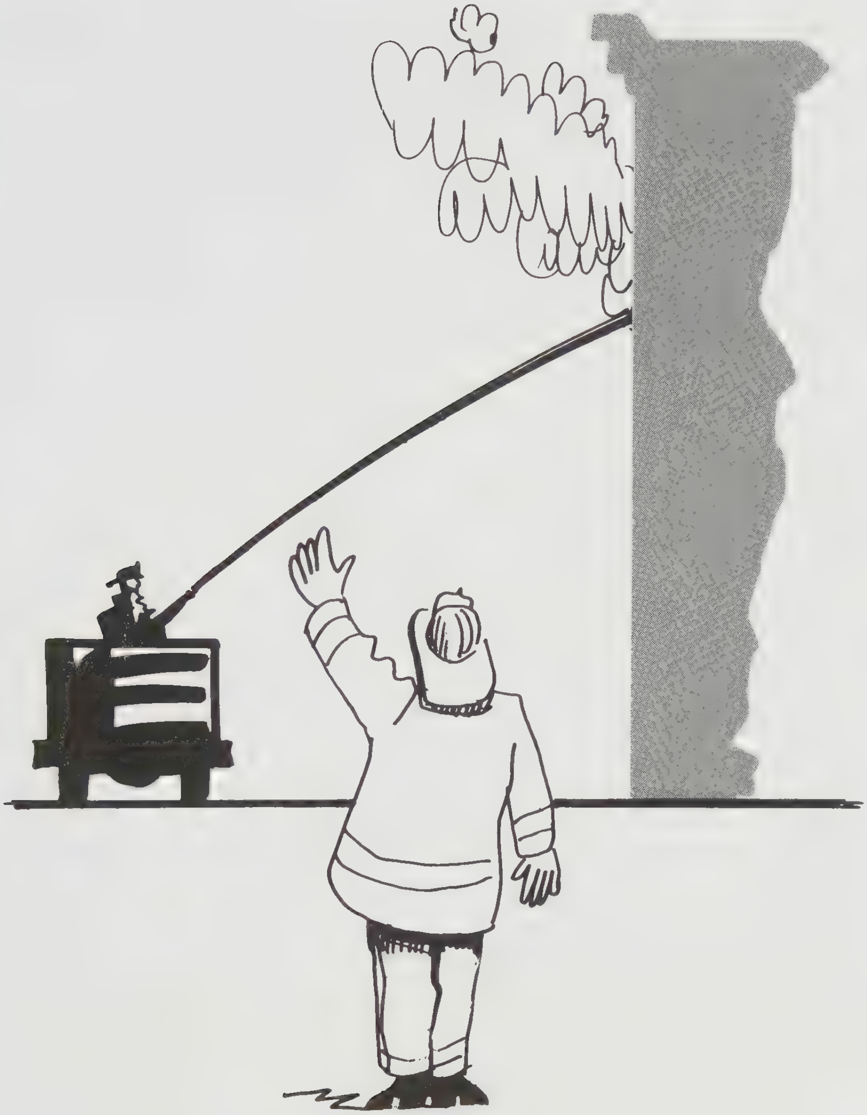


Figure 12.8. *A firefighter stationed some distance away from a master stream and facing it at a right angle has a better view than the operator and can guide him.*

Moving the Stream

Remember that a stream of adequate volume will extinguish all the fire it can extinguish in less than a minute. To keep playing it in one location for more than a minute does more harm than good. It not only causes unnecessary water damage but also moves a lot of air in front of it, especially a fog stream, and this entrained air may fan the fire at points the water doesn't reach. Therefore, master streams should be moved or shut down after a minute's use in one spot—and even sooner if they have attained the desired effect.

Of course, there is an exception where the main purpose of the stream is to flood the building. Upper-floor flooding is a last-resort tactic which is sometimes quite effective. It is accomplished by pouring heavy streams into the floor above the fire so that the water will run down between the walls, through pipe chases and other arteries, and even through the cracks between floor boards, and thus extinguish the fire or at least arrest its upward travel. Often this flooding will not completely extinguish the fire but will slow it to the point where hand lines can be moved in to complete the job.

13

Pre-Fire Planning

WHEN A FIRE department is acquainted with the potential of a fire before it occurs, that department has an advantage over the fire, provided that it makes preparations in keeping with the need shown by the earlier study. It is of little use to identify and isolate firefighting problems, if nothing is done to offset them. The elements of a pre-fire plan should not only pinpoint needs but provide for meeting them. Target hazards and their peculiar features should be identified. The requirements for combating a fire in any of them should be studied, and plans should be prepared.

Pre-fire planning will identify major problems, prescribe what is needed to meet them, and provide for meeting such needs. A pre-fire plan should not go too deeply into step-by-step actions. The more it does so, the more chance of error exists because of the fire departing from the script. There are too many possibilities of fire behavior for all of them to be catalogued and prescribed for in detail. For instance, in a school building three stories high, with 20 rooms on each floor and five in the basement, there are 65 rooms of potential origin. It is conceivable that detailed planning would require a different approach for as many fires as there are points of probable origin.

The same would be true of a shopping center in which there were 65 stores. One detailed pre-fire plan would not be sufficient. It was in such a situation many years ago that the deficiencies of detailed pre-fire plans showed vividly. When both shopping centers and pre-fire plans were new to the fire service, a certain department developed a detailed plan for a shopping center. The plan called for Engine 1 to take a certain hydrant, Engine 2 to take another hydrant, and Ladder 1 to place ladders at a given point. Then one day an alarm was received for a fire in that shopping center. The two engine companies took their designated hydrants, the ladder company went to its assigned location, and confusion reigned until the fire was traced to a closet in one of the stores and extinguished with a hand extinguisher.

Another weakness in step-by-step pre-fire planning is the possibility of a major plan component being missing when the time comes. For instance, if Engine 2 is supposed to take a hydrant on Main Street and stretch a line to the rear of the building, what happens if Engine 2 doesn't arrive because it is at another fire, or because it broke down or had an accident en route?

Ordinarily, the plan should identify all features of an occupancy that might affect firefighting tactics, especially those that are unusual or dangerous. For example, when I was a lieutenant, I inspected a 35-story office building which had a church occupying the lower part of the building. It was constructed just like any other church, including a huge hanging ceiling space—but in this case there were entrances to the hanging ceiling from the fifth floor of the office building. This information would be of great value if there were a fire in the church.

The essential features of a reasonable pre-fire plan are:

1. A list of all the hazards present, including building features, contents, and processes
2. Access points
3. Ventilation points
4. Built-in protection and how to utilize it (sprinklers, standpipes, other)
5. Water supply—location and limitations
6. Structural weaknesses, including horizontal and vertical openings, lack of fire stops, weaknesses that could lead to collapse, and so on
7. Structural strong points—the location of fire walls, parapets, and the like
8. An application of the ideal-rate-of-flow formula to determine water needs, personnel needs, and pumper needs
9. Provision for the prompt supply of the needs determined in item 8 above, through additional alarms, special calls, or mutual aid
10. The need for cooperation of other agencies and a prompt means of alerting them, along with an understanding on both sides as to why they are needed and what they are to do

It should not be necessary to go into great detail as to what lines should be stretched, to and from where, and by whom. The variations of fire in a large structure are so limitless as to defy strict prescription. For example, a certain fire department pre-fire-planned their largest hotel. The plan included step-by-step procedures for the placement of hose lines by all the first-alarm companies in case of a basement fire. They had a basement fire there, and all units followed the established procedure. Unfortunately, the fire did not. It happened to find a vertical duct, traveled quickly to a penthouse restaurant, and broke out there 20 stories above the basement, to which the department had committed all first-alarm units.

STRESS ON NONVARIABLES

The matter of water supply is one feature of pre-fire planning that is not variable and which can be well analyzed in advance. The location of hydrants, their capacity, water main sizes, and points for drafting water can be determined long before the fire occurs. Weaknesses can be discovered and plans made for offsetting them. Even relays and shuttles can be planned.

In pre-fire planning, all built-in fire protection equipment should be identified. The way it works should be learned and the locations of its key components noted. This procedure should be followed for sprinkler systems, standpipes, and other arrangements such as halon or carbon dioxide systems. It is especially valuable to know where siamese connections and control valves can be found when sprinkler systems are present. Plans should ensure that such systems are augmented or shut down, as the situation may require.

POST-FIRE ANALYSIS

There has been increasing emphasis on the value of "post-mortem" examinations following a serious fire. There are lessons to be learned from fires if the subject is properly approached. It is a delicate area, because the disclosure of error can become personal. Therefore, an effort should be made to keep the study objective and impersonal. Deputy Fire Marshal Joseph T. Deichman of the Chicago Fire Department developed a well-structured critique format which permits the objectivity desired without sacrificing its value as a means of improving efficiency. The critique plan is so good that it is given here in its entirety with permission of Chief Deichman.

TARGET HAZARD: LARGE LOSS of property and or LIFE
SPECIAL HAZARD
TRANSPORTATION HAZARD

Post-fire analysis starts at the fire scene immediately after the fire is extinguished to:

1. Locate the point of fire origin.
2. Determine the cause of the fire.
3. Trace the travel of the fire.

Upon returning to headquarters:

1. Collect information concerning the fire.
2. Review and study individual fire company reports.
3. Prepare a sketch of the fire building.

A Questionnaire Guide

To analyze: (*a*) What was done, and (*b*) Could it have been done better?

1. *Origin:* Were the possibilities of arson thoroughly investigated? Should the cause of the fire emphasize the need for increased fire prevention activities?
2. *Detection:* Would automatic detection devices have been of benefit?
3. *Alarm:* Was the alarm reported, received, and transmitted correctly?
4. *Response:* Were the proper equipment and personnel dispatched? Was the correct route taken?
5. *Extent of fire:* What was the extent of the fire upon arrival of the fire department? Did the fire continue to spread after firefighting operations had commenced?
6. *Size-up:* Was the proper size-up made by the first-arriving officer?
7. *Rescue:* Were rescue efforts successful?
8. *Ventilation:* Was the building adequately ventilated?
9. *Forcible entry:* Was the building opened so that damage was held to a minimum?
10. *Hose layouts:* Were lines of the correct size used and placed according to the fire situation?
11. *Hose streams:* Were hose streams properly directed and applied?
12. *Salvage:* Were salvage operations effective?
13. *Overhaul:* Was the fire completely extinguished? Was the building cleared of debris? Was water completely removed?

Was sprinkler protection restored? Was the building properly closed up? Was the building turned over to custody of the owners or proper authorities?

14. *Traffic control:* Did the police department assist in traffic control? Did you open the street for traffic as soon as possible?
15. *Utilities:* Were gas, water, and electrical services properly handled?
16. *Investigation:* Was the investigation made at the scene adequate to furnish the necessary information for a complete report?
17. *Public relations:* Did the actions or performance of the fire department enhance or retard public relations?
18. *Your composure:* Were you in command of yourself as well as in command of the fire situation? Were your actions and attitudes those of a leader?

Evaluation Standards

There is a great need to establish standards whereby a fire operation can be measured as to effectiveness. The following are some methods of measuring the results of fire operations:

Grade the various operations.
Grade values: 5 = Very good
4 = Fairly good
3 = Fair
2 = Fairly poor
1 = Poor

Example of application of grades:

Operation	*Grade*
Alarm	5
Response	1 (wrong route taken)
Rescue	- (no rescues required)
Ventilation	1 (too late)
Forcible entry	5
Hose operations	4
Ladder operations	2
Extinguishment	2
Salvage	1 (no covers employed)
Overhaul	5
Total =	26 ÷ the 9 items graded = 2.9 (less than Fair)

This fire operation can now be compared as to effectiveness with any other fire operation similarly graded.

Another method of measuring the effectiveness of fire operations is to apply a common denominator.

Example: Calculate the number of cubic feet in the area involved in fire:

Basement: 20 × 40 × 7 feet = 5,600 cubic feet
First floor: 48
Attic: 20 × 40 × 4 feet = 3,200
Total = 8,848 cubic feet

Divide this total by 1,000 (this factor represents the number of cubic feet in a typical small room measuring 10 × 12 × 8 feet = 960 cubic feet).

8,848 ÷ 1,000 = 8.8, or 9

Then 9 is the common denominator for this particular fire.

Applying the common denominator:

Personnel:	First Engine responded with	5 firefighters
	Second engine responded with	4 firefighters
	Truck company responded with	5 firefighters
	Squad company responded with	6 firefighters
	Chief and aide responded with	2 firefighters
	Total	22 firefighters

22 ÷ the common denominator, 9 = 2.4 firefighters.

This fire operation can now be compared as to the number of firefighters used per fire with any other fire.

Man hours:	First engine	worked 2.0 hours × 5 firefighters =	10.0
	Second engine	worked 1.0 hours × 4 firefighters =	4.0
	Truck Company	worked 1.8 hours × 5 firefighters =	9.0
	Squad Company	worked 1.6 hours × 6 firefighters =	9.6
	Chief	worked 1.7 hours × 2 firefighters =	3.4
		Total man hours	36.0

36 ÷ the common denominator, 9 = 4.0 man hours.

This fire operation can now be compared to the effective employment of firefighters present with any other fire operation.

Water used:
In basement:
one 2-1/2-inch line for 3 minutes (3 × 250 gpm) = 750 gallons
one 1-1/2-inch line for 4 minutes (4 × 75 gpm) = 300 gallons
On first floor:
one 1-inch line for 1 minute (1 × 25 gpm) = 25 gallons
In attic:
one 1-1/2-inch line for 6 minutes (6 × 75 gpm) = 450 gallons
one 1-1/2-inch line for 4 minutes (4 × 75 gpm) = 300 gallons
Total water used = 1,825 gallons

1,825 gallons ÷ the common denominator, 9 = 203 gallons.

This fire operation can now be compared as to the amount of water used per fire area with any other fire.

Scientific research would abhor our attempts as described above. They would probably research a fire operation by first calculating the number of BTUs produced by the fire and the amount of water required to absorb these BTUs. Comparing this result with the amount of water actually used in fire extinguishment would indicate the effectiveness of water application.

An engineered research into a firefighting problem would also require accurate water measurement by the installation of meters on the hose lines or pumpers.

A Post-Fire Conference

Reviewing the operations at a fire in a conference affords an opportunity for the members of the fire department who were not present at the fire to benefit from the experiences of those who were present. Post-fire conferences are also instructive for those members who were at the fire, but whose activities were confined to a limited area or sector, by permitting them to gain a knowledge of the overall strategy and operations at the fire. Finally, a post-fire conference is an opportunity to discuss how the operation could have been accomplished more effectively. Obviously, a post-fire conference is a training technique.

The preparations needed for a post-fire conference include:

1. Accurate and fairly complete information
2. A good sketch of the fire to be used as a visual aid, and also photographs, if available
3. A plan for systematic interrogation of personnel in proper order of sequence of operations

Conducting a post-fire conference requires a great deal of tact and diplomacy in order to obtain maximum participation by those in attendance. Comments of a critical nature regarding an operation should be toned down on the basis that the criticism is a training process and not a "bawling out."

A checklist for conducting a post-fire conference should include:

1. Have the proper people been invited to attend the conference?
2. "Set the stage" so that the participants will know the reasons why they are attending the conference.
3. Describe the fire situation so that the participants will be familiar with the problems involved.
4. Use visual aids such as sketches and photographs.
5. Review the firefighting operations step by step.
6. Conduct the discussion in such a manner that the participants will feel relaxed and will become willing to contribute ideas and relate experiences.
7. Handle the criticizing of mistakes as a learning process.
8. Praise as well as criticize.
9. Ask if there are any questions or comments.
10. Recognize all questions, comments, and suggestions.
11. Conclude the conference by expressing your confidence in the continued improvement in the officers and crew members.

A properly conducted post-fire analysis will achieve the following objectives:

1. It will finalize the fire report.
2. It may indicate the need for tactical procedure changes.
3. It may point out the need for increased emphasis on certain drill evolutions.
4. It may point up the need for emphasis on certain aspects of fire prevention activity.
5. It may point up the flaws in or the lack of fire protective installations.
6. It may indicate the need for closer cooperation with the police, utility companies, and so forth.
7. It assists in the formation of your judgment of personnel.
8. It educates the participants.

Thus does Chief Deichmann conclude his post-fire analysis.

14

Major Fires

THE SUCCESSFUL control of major fires depends not only on the selection of the correct tactics, but also on good direction and coordination. When large numbers of firefighters and much equipment are involved, it is necessary to establish better than usual means of coordination and control. The heart of any direction and coordination system is the control center, but the instrument through which it operates is the command post. It would be well to

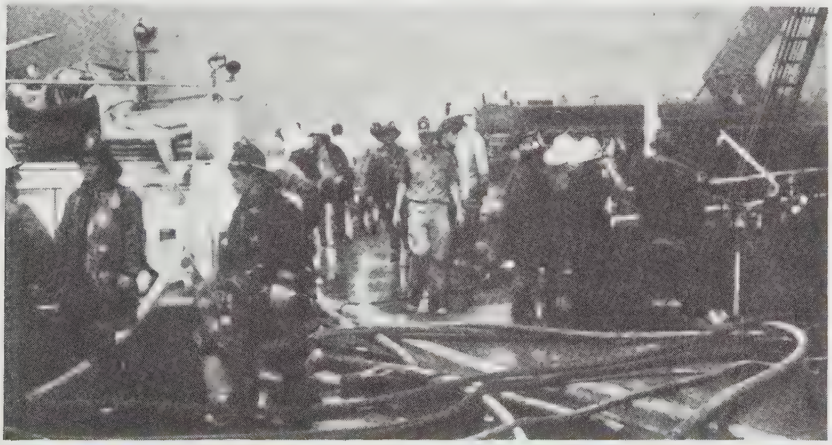


Figure 14.1. Large numbers of firefighters and apparatus create problems unless provision is made for orderly arrival and assignments, which was apparently not done at the fire shown. Firefighters seem to be milling around.

explain the difference. Ordinarily, a field command post is all that is required, but at an exceptionally large and long-drawn-out fire or emergency, a control center may have to be used. Such occasions might be called for by a series of riot-inspired fires in several different sections of a city or county or by a civil defense emergency such as a flood.

A control center is usually established and equipped—and sometimes staffed—long before an emergency occurs. The command post is set up in the field as the need for it arises. One of the most important functions of the command post is to maintain good communications among all levels of command. You can't direct if you can't communicate. Therefore, there should be a "communications officer" who is well versed in communications processes and equipment. Communication is a two-way street that requires information gathering and information dispensing. To do it effectively requires the use of radio, telephone, and television—not forgetting the written and the spoken word. Closed-circuit television, a relatively new communications tool in the fire service, allows the chief officer to see (without moving) what is happening on all fronts of the fire building. Television, in effect, puts the chief on the scene where he does not have to depend on oral descriptions. A further advantage of closed-circuit television is that it can be recorded for post-fire discussion, study, and training.

If orders are to be carried out effectively, all efforts must be coordinated. The total effort can be subdivided into both vertical and horizontal functions. Vertically, the considerations are the tactics to be employed on all sectors of the fire. Horizontally, the factors are water supply, safety, and logistics. The third item includes fuel for apparatus and the possible repair and replacement of vehicular parts and accessories. One of the most interesting facts learned from the Detroit riots was the extensive damage done to apparatus tires by broken glass in the street.

LOGISTICAL FACTORS

In operations of long duration there will be a need to feed personnel and to provide rest for them. Large-scale feeding and rest facilities are usually beyond a fire department's own capability and may require outside help.

The arrival of large numbers of apparatus and personnel will create problems unless provision is made for orderly arrival and dispersal. A staging area should be set aside for this purpose so that the incoming units will have a place to gather and await assignment.

When this area isn't provided, there is a good chance that companies will wander and perhaps even assign themselves as they see fit.

Care should be taken to keep track not only of each unit but of each firefighter. A sudden building collapse, for instance, would require a quick head count to be taken to discover if anyone were missing. It is also desirable to keep track of the progress and the work performed by each unit so that a total picture will be available for post-fire analysis.

T PAR

The welfare, as well as the safety, of the operating forces should be kept foremost in mind. Provisions should be made for ample rest and feeding, which is not only humanitarian but practical, too, because efficiency will drop rapidly with fatigue and hunger.

Medical care for injured firefighters must be provided by persons competent to do so, and there should be someone present to evaluate injuries and make decisions as to whether the injured should return to duty, be relieved from duty, or sent to a hospital.

Large-scale operations will attract public attention. Therefore, the news media must be kept informed by the fire department and not be forced to rely on statements of police and bystanders. Photographic records should be made by the fire department for the purpose of future training, as well as records.

Liaison with other agencies should be maintained. Such agencies are police, National Guard, civil defense, welfare department, building department, medical services, public utilities, and other local, state, or federal agencies.

SPAN OF Contro

T The "series of fives" concept can be applied for line operations. The five units making up a task force can be composed of outside mutual-aid companies and one or two local units to give directions and maintain radio contact.

Many valuable lessons can be learned from the large-scale operations of the past. One I studied closely and can report upon with reasonable authority is the fire situation resulting from the Detroit riots of July 1967. It serves as a valuable case history replete with lessons on tactical, logistical, personnel, and communications problems, as well as fire behavior. In a five-day period, the alarms precipitated by the Detroit riots reached a total of 1,427. The normal alarms for such a period would have been about 600. Therefore it is clear that there was a load of 800 above normal for the five days (actually a four-day period, if measured in 24-hour segments from the start at 6 A.M., July 23, 1967) and a peak of 500 above normal on Monday, July 24.

Undoubtedly, more alarms were transmitted from the street boxes than were received. The boxes used in Detroit can transmit nine "pulls" with one winding. Several boxes were pulled more than nine times and became run down, thus opening the circuit and rendering that circuit useless until the run-down box could be rewound. In

Detroit, three days elapsed before linemen were able to rewind all the boxes.

This same situation could occur in almost any large city during a severe fire emergency. Also, a large number of simultaneous telephone calls from the one exchange can overcome the capability of that exchange to handle incoming calls and render its dial system inoperative. This instance actually happened following a fire and explosion on a Brooklyn pier in 1957.

Probably the greatest surprise to fire protection experts was the fact that there was so little fire spread in Detroit from so many fires. When you consider that in some cases there was no firefighting for extended periods and that in most cases a bare minimum of firefighting had to suffice, it seems miraculous.

The weather cannot be given any credit for this situation because it remained dry and fairly windy throughout the riot period. Only 2.45 inches of rain had fallen in the 22 days of July until the start of the fires. No measurable amount fell during the balance of the week.

Weather

Date	*Day*	*Sky*	*Temperature*			*Humidity*	*Wind: 4 P.M.*		*Wind: 10 P.M.*	
			High	*Low*	*Mean*	*(10 P.M.)*	*Direction*	*Velocity*	*Direction*	*Velocity*
23	Sun.	Partly cloudy	85	68	77	63	SW	16	SW	15
24	Mon.	Partly cloudy	90	68	79	54	W	16	WNW	10
25	Tue.	Clear	83	62	73	61	WNW	17	WNW	9
26	Wed.	Partly cloudy	83	55	69	84	SW	14	SSW	7
27	Thur.	Cloudy	—	—	72	84	SW	13	SSW	4

Not every fire was fought. In many cases, the rioters would not let the firemen get to the fire, or forced them to withdraw after arrival. One engine company was forced to withdraw 12 times, and the aggregate total for all companies was 283 times. This fact should not be interpreted to mean that firemen were forced to withdraw from that many fires. Our analysis of reports indicates that firemen withdrew from about 60 fires.

Limitation of Fire Spread

How far did these fires spread? No fire crossed any street, and only a few crossed narrow alleys. In no case was an entire city block burned out. The largest area destroyed that we could find was in the block bounded by Linwood, Blaine, Pingree, and LaSalle Boulevard. About two-thirds of the buildings on that block were destroyed by the

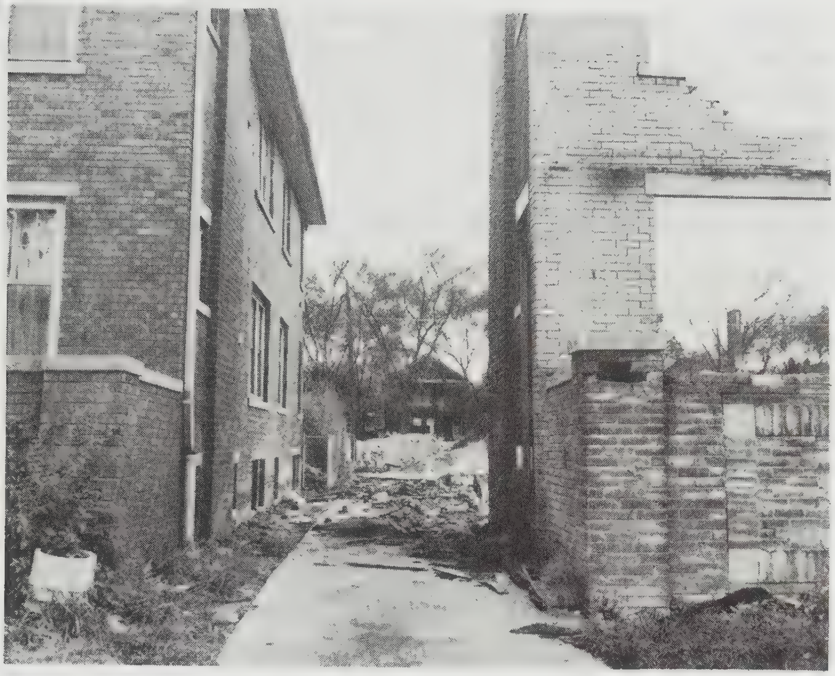


Figure 14.2. *The undamaged building at the left was saved by a man wielding a garden hose, despite the fact that the building at the right was completely destroyed.*

spread of fire from a single ignition. (We regarded this fire as being of sufficient interest for special study and will discuss it separately, later in this report.) In cases where several adjacent business buildings were destroyed, it was impossible to tell with any certainty how many of the buildings were ignited separately. But where fires extended along side streets through residential structures, it could be safely assumed that these buildings ignited from each other. The most extensive of these fires that we found involved nine dwellings in a row.

What are the apparent reasons for such comparatively little fire spread under such adverse conditions? For one reason, there were no indications of fires caused by flying brands, which is particularly interesting in view of the fact that the weather was warm and windows would naturally be open. Another reason is that roof coverings were not vulnerable to fire. Wood shingles were not present in Detroit and the asphalt shingles and built-up roofs resist ignition from sparks and brands.

In the business blocks, fire walls were a definite factor. Where each of two adjacent buildings had its own fire wall, there was no extension of fire from one building to the other. Where openings had been made in such walls, buildings on both sides were destroyed; it was common to see a building burned out completely between fire walls, with all combustible stock and structural parts completely consumed. Yet the buildings on either side remained undamaged. It seems that Detroit was fortunate in not having light and air shafts between the mercantile buildings involved, a condition prevalent in store-apartment combinations in some other cities.

Importance of Building Spacing

The next limiting factor seems to be the spacing between dwellings and, perhaps, this factor should be coupled with the presence of many brick-walled dwellings. The brick walls would limit the ignition and entry points of fire to windows and roof, and limit heat radiation from a burning dwelling to the same points. Heat radiation, as we mentioned earlier, from such point sources diminishes with the square of the distance, whereas heat radiation from a line source, such as a fully involved frame dwelling, decreases only directly with the distance.

Although the fire spread from building to building in a residential block is influenced by the type of walls, the spread is necessarily slow regardless of wall type. Consider that in order for one building to ignite another by radiant heat, it first must become involved with fire to the point where it is radiating a great amount of heat. Even where ignition and fire spread throughout the first structure are optimum, at least 20 minutes could elapse before the heat from the burning structure menaces the exposed structure. Then, depending upon the distance between the two buildings, the exposed structure will take time to absorb sufficient heat to ignite. Although the situation may vary considerably with construction and distance, it might be said that spread from structure to structure in closely built dwellings might take one half hour per building. Therefore, four hours might be needed for a fire to progress through eight dwellings in a row. There are indications that this extension may have happened at some of the Detroit fires.

None of the Detroit fires reached fire-storm proportions, and none approached what could truly be called a conflagration. The lack of fire spread in Detroit,when added to similar results in other cities when fires burned unchecked, would indicate that the probability of urban conflagrations or mass fires is not as great as formerly believed.

The common method of ignition in Detroit seems to have been the so-called "Molotov cocktail"—a bottle of gasoline with a wick which is thrown into or against a building after the wick has been ignited. The success of this device is largely dependent upon where it lands. In most cases in Detroit, the ignitions took place in stores that had been looted, which meant that there usually was an easily ignited fuel source in the form of the rubbish left from the looting. The rubbish contained much cardboard and paper that had been scattered in such a way as to provide easy ignition and fast spread. Furthermore, broken windows admitted a good supply of oxygen. Thus, there were ideal conditions for the fast spread of fire at a time when fire defenses were at a minimum.

As mentioned earlier in this chapter, I decided to concentrate on one particular fire for special study. The one selected was chosen for four reasons: It appeared to be the most extensive; there was an aerial photo available that had been taken when the fire was in progress; the side streets were occupied by a common type of residential structure; and there was reasonable certainty that the fire resulted from just one ignition.

This fire started shortly before noon on Sunday, July 23, and was still in progress at 9 P.M., according to a resident of the block who called in the alarm for the fire and remained on the scene throughout.

According to the resident, the fire started in a rug-cleaning establishing on Linwood Street, which is the west end of the block. There was a brisk wind (probably about 15 mph) from the west at the start and throughout. The fire department answered the alarm, but the firefighters were first delayed by rioters and then forced to withdraw by snipers. The fire spread north and south to the other business buildings on Linwood and leaped a 20-foot alley to attack the dwellings on Blaine and Pingree.

A particularly interesting feature of this fire is the fact that a dwelling at 2540 Pingree Street was not damaged, and remained as an undamaged island amidst the destruction. By the owner's account, she and a male friend evidently did a yeoman job of protecting the building with a garden hose for several hours, until firefighters were able to get through and save her house by attacking fire in a dwelling ten feet to the east which was completely destroyed. According to eyewitnesses, the fire on this block burned for at least nine hours.

As best we could determine, from records and remains, nine mercantile buildings were destroyed on Linwood Street, three dwellings (possibly five) were demolished on Blaine Street, and nine on Pingree. The burned-out area covered approximately 62,000 square feet, or about two-thirds of the block.

The residential structures on Blaine and Pingree were all of the same type—2½-story, brick-walled, wood-roofed with asphalt-combination shingles. They were about 20 feet wide and 35 to 40 feet long and were spaced 10 to 12 feet apart.

According to the surveys made by the Detroit fire marshal, a total of 561 buildings were damaged by fire. Our analysis of his reports indicates that 86 percent of these were demolished or damaged beyond repair. The total, however, represents only an extremely small

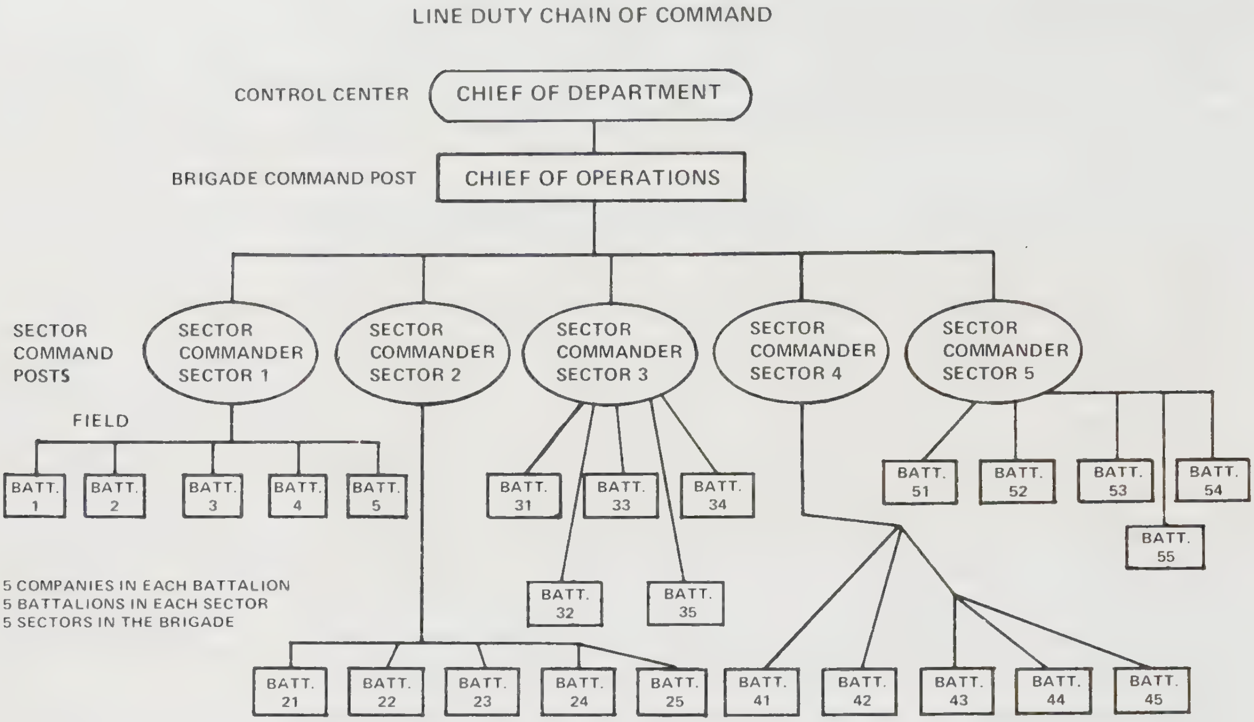

LINE DUTY CHAIN OF COMMAND
CONTROL CENTER
CHIEF OF DEPARTMENT
BRIGADE COMMAND POST
CHIEF OF OPERATIONS
SECTOR COMMAND POSTS
SECTOR COMMANDER SECTOR 1
SECTOR COMMANDER SECTOR 2
SECTOR COMMANDER SECTOR 3
SECTOR COMMANDER SECTOR 4
SECTOR COMMANDER SECTOR 5
FIELD
BATT. 1
BATT. 2
BATT. 3
BATT. 4
BATT. 5
BATT. 31
BATT. 33
BATT. 34
BATT. 32
BATT. 35
BATT. 51
BATT. 52
BATT. 53
BATT. 54
BATT. 55
5 COMPANIES IN EACH BATTALION
5 BATTALIONS IN EACH SECTOR
5 SECTORS IN THE BRIGADE
BATT. 21
BATT. 22
BATT. 23
BATT. 24
BATT. 25
BATT. 41
BATT. 42
BATT. 43
BATT. 44
BATT. 45

Figure 14.3. *Organizational chart 1, for large-scale operations.*

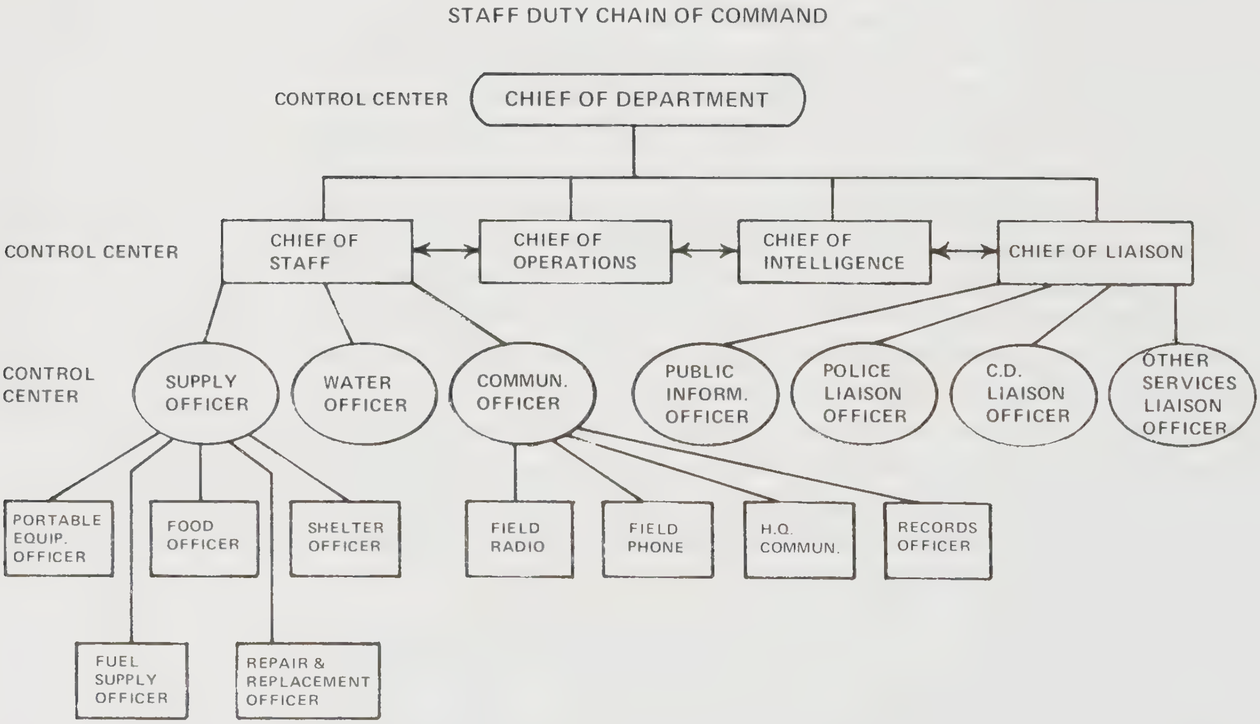

STAFF DUTY CHAIN OF COMMAND
CONTROL CENTER
CHIEF OF DEPARTMENT
CONTROL CENTER
CHIEF OF STAFF
CHIEF OF OPERATIONS
CHIEF OF INTELLIGENCE
CHIEF OF LIAISON
CONTROL CENTER
SUPPLY OFFICER
WATER OFFICER
COMMUN. OFFICER
PUBLIC INFORM. OFFICER
POLICE LIAISON OFFICER
C.D. LIAISON OFFICER
OTHER SERVICES LIAISON OFFICER
PORTABLE EQUIP. OFFICER
FOOD OFFICER
SHELTER OFFICER
FIELD RADIO
FIELD PHONE
H.Q. COMMUN.
RECORDS OFFICER
FUEL SUPPLY OFFICER
REPAIR & REPLACEMENT OFFICER

Figure 14.4. *Organizational chart 2, for large-scale operations.*

percentage of all buildings in the affected areas. Actually, although these fires were all in completely built-up urban areas, less than ten buildings per square mile were damaged. How many separate ignitions occurred is not ascertainable, but inasmuch as there were fires in 167 different blocks, there must have been at least that many ignitions and probably there were more than twice that number.

COMMAND STRUCTURE

Figures 14.3 and 14.4 show an organizational structure for large-scale emergencies, such as might occur from enemy action, civil disturbances, or natural disaster, as well as a conflagration. The two charts are given separately for clearer illustration, showing line duties as distinct from staff duties. Line duties are concerned with operations; staff duties with support. Close coordination between them is essential. That is why Figure 14.4 shows connections by way of horizontal arrows that indicate an exchange of information, not orders. The orders come down vertically on the chart, as shown. The flow of orders is directly down; the flow of information is up, down, and horizontal.

The operational chart is based on the "series of fives." The five sector commanders each command five battalions; the five battalion commanders direct five companies each. If there is an officer and five firefighters in each company, then this chart provides for the coordination and control of 750 firefighting personnel in 125 companies. In cases where this number would be insufficient, another sector, founded on another series of fives, could be established, and so on.

Staff positions do not lend themselves well to a strict series of fives in all echelons; however, the span of control is either five or less at each level to assure that it is not too large.

The command structure requires allocation of positions for the echelons which will be functioning at the control center, brigade command post, sector command post, and in the field. It should be realized that the field positions should be fluid—to a certain extent—rather than as rigid as the command posts.

This chart attempts to limit the total personnel at the control center to a necessary minimum. The fewer people operating there, the less will be the confusion. The same is true of command posts, and especially of communications centers. They should not be allowed to become "hangouts" or a place for the idle curious to gather, regardless of rank.

RIT ↓ TEAM

A serious effort should be made to keep close track of all units and all personnel on duty. Then if a unit, or even one firefighter, is missing, the fact can be discovered and the place of disappearance marked for immediate action.

An accurate record should be kept of all occurrences and activities for future analysis and planning. These records should be made permanent. Other record keeping involves the hours worked by each individual, and a record of personnel injuries and treatment. In recording the events of an emergency or fire situation, personal observation should be encouraged to augment the usual dry statistics. These observations, recorded while fresh in mind, could prove valuable much later (Figure 14.5).

Not enough can be said for the value of communications in large-scale operations. Regular communication media may be found wanting in major emergencies. In some of the large-scale operations during the civil disturbances of the late 1960s, several fire departments could not communicate by radio with mutual-aid units because they operated on different frequencies. Now we find that in some metropolitan areas all fire departments are sharing a mutual-aid frequency, as well as maintaining their own for local use. This process is accomplished by the relatively simple installation of dual crystals that permit two-channel capability. The only limitations to this capability are power and distance. Both of these factors can be well determined in advance of an emergency which could require mutual-aid radio transmissions.

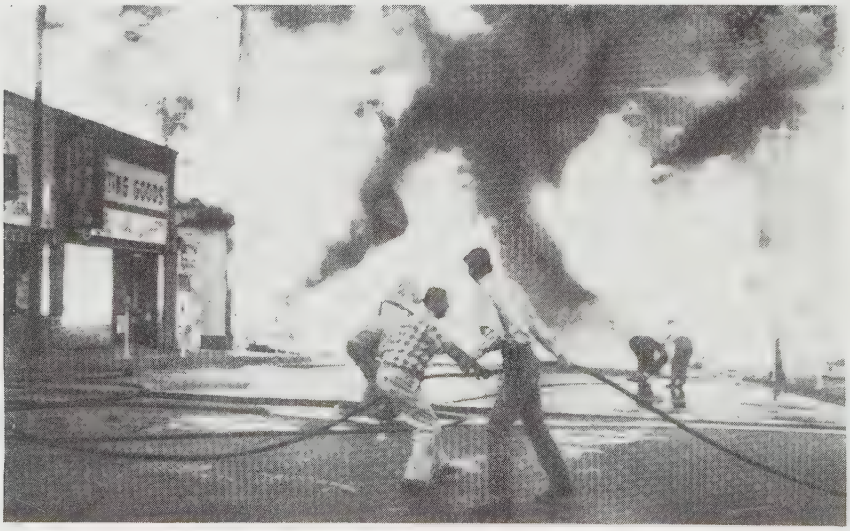


Figure 14.5. *Conflagrations are not just a problem of the past. This photograph shows a fire that has leaped across a wide avenue.*

STAGING AREA

Two Football Fields

As mentioned previously, calling a large number of firefighters and apparatus to a specific area can present problems. Therefore, provision should be made for their orderly arrival and deployment. They should be instructed to report to a staging area and there await further instructions. Then the chief in charge can call upon the individual units in line to leave the staging area and proceed to where their services are needed.

The staging areas can be school yards, parking lots, or just the street on which the command post is located. The street can be blocked off and companies aligned along the curb in a response pattern. As units return from a completed task, they can get on the end of the line to take their proper turn.

A system of equitable distribution of company labor leads to the question of reasonable labor for the individual. Nearly all firefighters are willing to sacrifice their time, risk their lives, and suffer physiological distress in order to accomplish objectives at a major fire. The problem is to keep them from overextending themselves by working at a peak too long.

It is better for the individual, and for the total effort as well, if that person is given frequent relief and rest and not allowed to reach the point of exhaustion. As firefighters become tired, they not only become less efficient, but they become more prone to injury and mistakes. The more demanding the situation, the more frequent should be the relief and the longer the rest period. This principle applies at any fire, regardless of size, but is of most concern when the effort is a prolonged one.

NEEd Protocol For Rehab.

LACK OF EXPERIENCE

There are very few fire chiefs or officers today who have had command experience at an urban conflagration. None of the riot-caused fires in the 1960s reached the conflagration stage, and there have been hardly any other fires involving several built-up city blocks. Therefore, if we wish to be prepared for a conflagration (in this context, a single fire involving more than one city block in a built-up area), we must rely on history for much of the information on which the strategy and tactics are based. As has been said earlier in this book, conflagrations were once fairly common occurrences, but not of late. There is no guarantee that there will never be another, however, and no sure knowledge as to where one will occur. For those reasons,

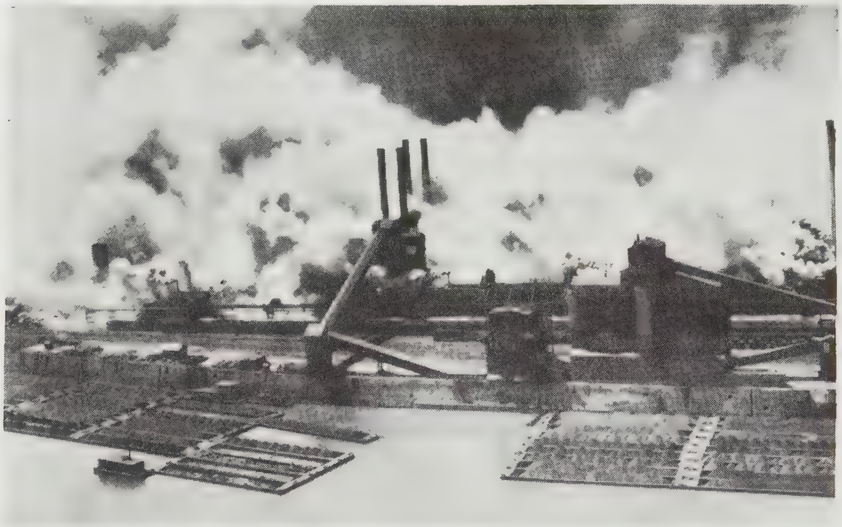


Figure 14.6. *Large-scale fires such as this one occur so infrequently that chief officers have little opportunity to acquire experience in their extinguishment.*

and the fact that a conflagration is so awesome and the consequences so awful, every fire department should be prepared for one. This preparation calls for good mutual-aid and major disaster plans, plus a knowledge of conflagration behavior and the tactics needed to combat it.

Conflagrations usually get under way for either of two reasons. One is that the fire was already beyond the capability of the firefighting forces when they arrived. The second is that they failed to contain a fire that could have been contained. The reasons for the latter are several:

1. Failing to protect exposures
2. Making a weak initial attack (i.e., small hose lines and insufficient volume of water)
3. Not taking precautions with brands that are flying downwind

In the first of the above cases, we find that officers, who have never had a fire extend to an exposure, are not as inclined to expect it as those who have experienced it. The time-honored strategy of confine, then extinguish should not be forgotten, even though an officer has gone to 1,000 fires in a row which required no exposure protection. Exposure protection is two-way. Hose streams should be directed against the exposed structure and hose lines taken inside it to prevent fire from entering. The British developed exposure protection to an art

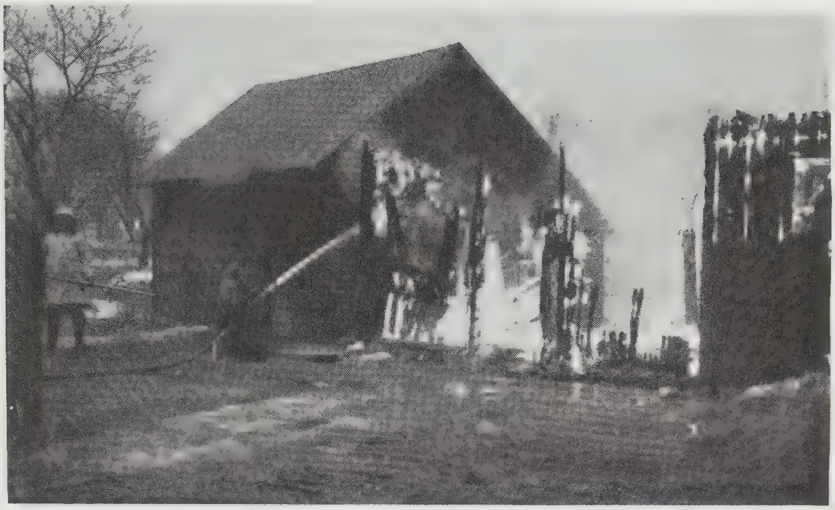


Figure 14.7. *In an experiment, the wood-frame dwelling at the right was permitted to burn to the ground. A similar building at the left was completely protected by one hose stream that kept its exposed wall wet.*

in World War II. They would leave a bombed building to burn while a small firefighting force kept the fire from spreading to adjacent structures. They would handle hundreds of such fires a week, without serious extension. For every one that extended, perhaps 50 were confined.

In some of our experiments in Wisconsin, we have burned a wood-frame dwelling completely without damaging a similar building six feet away. The technique consisted of keeping the exposed building wet on the side facing the fire, and keeping another hose stream on the fire building on the side near the exposure. Actually, one line can do both in a pinch, alternating from one building to the other.

T

An officer who starts his fire attack with a small stream does so from habit. He is so used to attacking a fire with 1- and 1½-inch hose lines that he may attempt this kind of an attack on a fire that is far beyond the capability of such streams. Then, by the time he realizes his mistake, the time wasted with the small line has allowed the fire to advance beyond any control.

NEED FOR BRAND PATROLS

The problem of flying brands depends upon three factors, each of which is not always present. The first is the generation of the brands, the second is the wind, and the third is the host fuel source for the

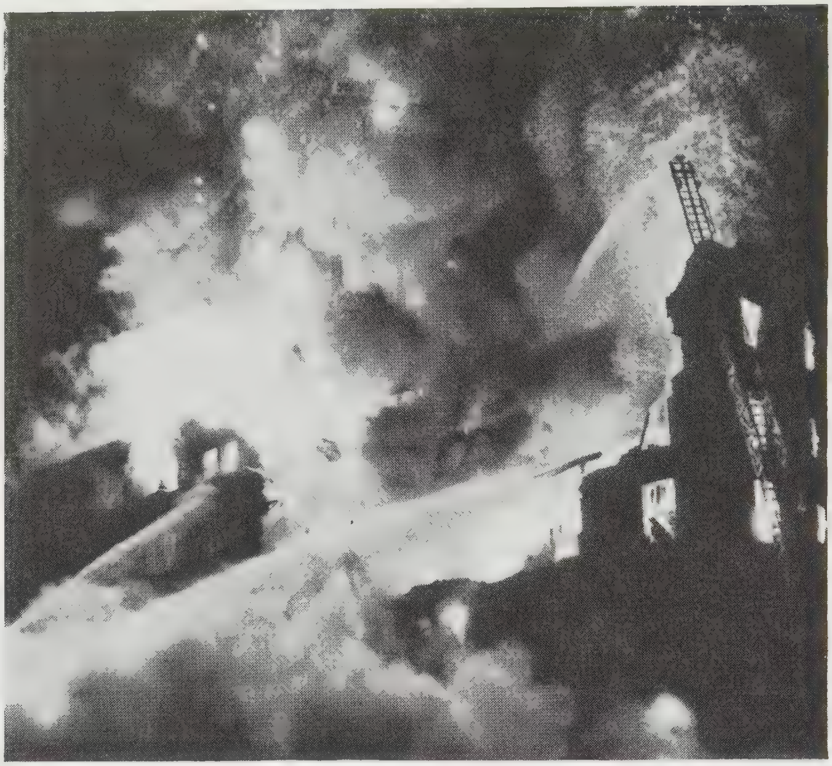


Figure 14.8. *The spread of fire by flying brands depends on the wind, and also on the host fuel on which the brands may land. Wooden roof shingles are a ready host, which may ignite quickly.*

brands (Figure 14.8). The last mentioned is the most important factor. If it isn't present, then the likelihood of fire spread by flying brands is not serious. Wood-shingle roofs are the host which will propagate fire readily. Other roofs may ignite when heated sufficiently by flame contact or by radiation, but only wood-shingle roofs will ignite from brands—and they will ignite easily. I have seen such ignition occur where brands traveled a quarter of a mile. Undoubtedly, it could happen where the distance is even greater.

Wood shingles are not the only ready host. I once saw a conflagration in New Jersey that developed when flying brands from a lumber yard landed in another lumber yard, six blocks away, and set off a second fire there that eventually merged with the first.

A large fire can spread by flying brands, convection, and radiation. All three require defense in depth. Brand patrols, equipped to snuff out incipient, brand-caused fires, should be well spread out downwind. The police can provide help in this task. Firefighters equipped with a pump tank or a garden hose can patrol in radio-equipped police cars downwind of the fire. They can look not only for brand-started fires, but can be sent to them by the police dispatcher relaying messages from the fire dispatcher. In turn, they can call for help when needed through the police dispatcher to the fire dispatcher.

In setting up a defense against convection and radiation, there should be provision for the first line of defense to be covered by a second line. If fire reaches the first line of defense and appears too much for it, an orderly withdrawal can take place so the second line then becomes the first line and the first becomes the new second, taking a new position behind it.

Careful judgment should be given to the selection of the site for a defensive stand. Natural obstacles to fire spread such as parks or other open areas, as well as fire-resistive buildings, should be considered. In the past, there have been frequent cases where a conflagration was stopped by a good fire wall in a single building. Some of the larger chain stores will not lease a building without fire walls. The knowledge of where fire walls exists is valuable in a conflagration situation.

LEARNING FROM THE PAST

The speed and direction of travel of a conflagration can be estimated from past case histories. The great Boston fire of 1872 took 16 hours to burn 1,000 buildings covering 70 acres. It jumped across 16 streets of various widths, mostly narrow. Most of the fire spread was by radiation, with considerable spread against the wind. Some of the wooden-exterior buildings burst into flame all at once after being subjected to radiant heating. In all, 26 blocks and a few half blocks were burned, as well as a few piers. The season was fall (November), and the fire was reported at 7:15 P.M. There was nothing unusual about the weather. An interesting aspect of this fire was that a rekindle attributed to an explosion of gas leaking from a main took another three blocks the following night.

The great New York conflagration of 1835 started at night in December, when the temperature was 17 degrees below zero. The fire burned for two days and destroyed 674 buildings, nearly all of which were brick and wood joist commercial occupancies located in a neighborhood of narrow streets, with no spaces between buildings and no vacant lots or parks. The hand pumpers of the period were not capable of enough pressure for streams to reach the top floors of several of the buildings involved.

If the above fires are examined for a fire spread time factor, it would appear that there was a considerable difference in the number of buildings ignited per hour, with an average of 62 per hour in Boston and only 14 per hour in New York. This fact could be due to the fact that the New York buildings were generally bigger and most of them had brick walls, but this possibility is only conjecture. Other factors could have been more important. The Boston fire presents a fire spread speed close to the maximum; the New York conflagration was nearer to average. Inasmuch as a conflagration has four sides, its spread is progressive. As each side increases in length, the more buildings are involved. A fire covering one square block is exposing four blocks; a fire covering two square blocks exposes six blocks; and one involving four square blocks exposes eight or ten.

HOLDING ACTIONS

If water supply is adequate, a fairly small force can defend a large front. Scrutiny of conflagrations and riot-inspired fires indicates that as little as 250 gpm per 100 feet of fire front can be effective in a well-fought holding action. In many towns, this amount would be beyond the capacity of the local water supply system. In other cases, the town's water storage would soon be exhausted. For these reasons, it is good practice to put as many pumpers to work from draft as can be done efficiently. (Probably the greatest flow ever applied at a fire was

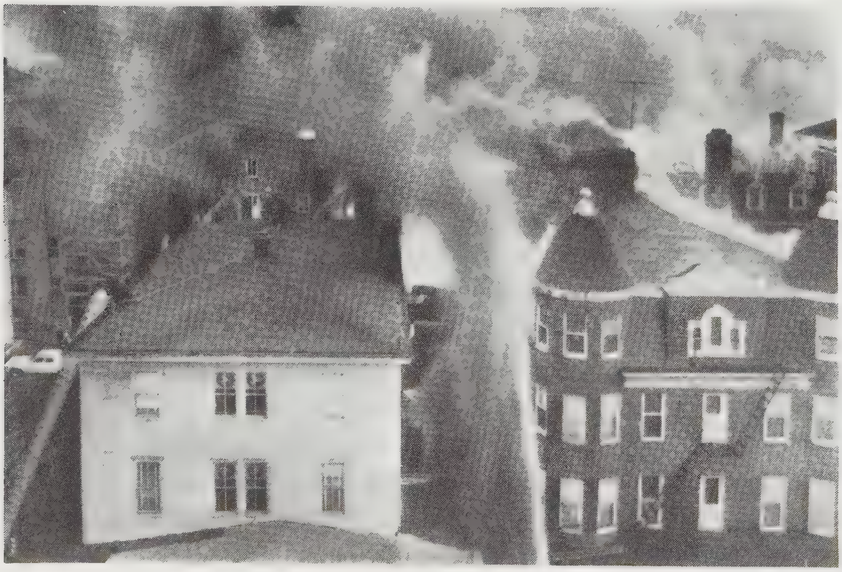


Figure 14.9. *Closely constructed combustible buildings in Atlantic City, New Jersey, have been subject to many large fires. The need for an ample water supply where such construction exists is apparent in this photograph.*

50,000 gpm supplied by 106 pumpers at the Chicago stockyards fire on May 19, 1934.)

T Attack on a conflagration demands not only a high rate of water application but also that it be applied with master streams. Sometimes the radiant heat is so great that firefighters cannot approach close enough to apply water from hand lines—even good, strong 250-gpm streams. The master streams must be strong enough to travel through the wall of heat and flame surrounding the fire and strike the fuel source. I have seen fires where 500- to 800-gpm streams were totally ineffective, but when streams from fireboats, delivering 2,700 to 7,500 gpm each, were used, the fires usually went out. Experience with heavy-caliber fire streams (from nozzle tips 3 to 5 inches in diameter) is what led to the design of the New York super pumper, which was actually a fireboat on wheels.

Only a very few American fire departments have nozzles capable of discharging over 1,250 gpm. I made a survey which showed that only a few cities had nozzle tips on land apparatus larger than 2 inches in diameter. (The 2-inch tip will discharge 1,189 gpm at 100 psi.) Some had fog nozzles capable of providing 1,250 gpm at 100 psi.

Although records show that conflagrations are now occurring at the rate of less than one per year, the reduced probability does not permit total ignorance of the hazard and means of handling it. On the contrary, it could be said that the lack of experience with such a situation demands a study of it. The things we may have to face, but with which we have the least experience, are those we should study most.

In the first edition of this book we said in the preceding paragraph that, although conflagrations were now infrequent, the reduced probability should not encourage us to ignore the problem and think that it is just a problem of the past. Hardly were the words written, when the largest conflagration in over forty years struck Chelsea, Massachusetts, and Chief Herbert Fothergill soon found himself in charge of the largest firefighting force ever assembled at an urban fire. It can be said to his and their credit that the fire was headed off and stopped.

By amazing coincidence, this conflagration started in almost the same location as the famous Chelsea conflagration of 1908 and thus gives an excellent basis for comparison. The fire of April 12, 1908, started on a dry, windy Sunday morning; the fire of October 14, 1973, started on a dry, windy Sunday afternoon, only 200 feet from the point where the first fire began. The wind was blowing from the northwest at about 40 miles per hour in both cases.

The 1908 fire, starting about 11 A.M., burned all the way across town until stopped by the Chelsea river about six hours later. Nineteen people died, 500 were injured, and 3,500 buildings on 1,440 acres were destroyed. The smoke column was visible for 50 miles in daylight; the glow in the sky at night was observed 90 miles away. Embers were sighted 18 miles downwind.

When the burned-out area was rebuilt with many three-story wood-frame buildings, about the only improvement was fewer wood-shingle roofs. The 1973 fire was discovered and reported promptly, but when the first alarm companies were dispatched at 3:56 P.M., they found a fast-spreading fire, which was already of considerable size. When it was over, about four hours later, 60 people had been injured (none were killed), and 300 buildings were destroyed over a 12-block area.

Mutual aid played a big part in both fires, but was much more effective in the second, because of two factors: motorized apparatus could travel long distances more rapidly than horses, and a strong, well-established mutual-aid plan was in effect. It provided assistance in an organized manner until 190 units with 700 firefighters were in Chelsea; however, supplying all the pumpers with fuel became a major problem.

The spread of fire was mostly by wind-blown flames, but radiation and flying brands also helped. Just as in 1908, railroad tracks provided a break on the north side, and the fire did not travel west of the point of origin. On the other two fronts, the fire was contained by judiciously selecting points to make a stand where there was some break or barrier. A successful maneuver was to place hose lines inside substantial buildings with fire-resistive walls, such as a large school and a fire station; these tactics were effective in keeping fire from entering through windows. The school, in particular, made a good barrier. Another successful stand was made in an area with many vacant lots. It appears that these natural breaks and barriers should be carefully selected and prepared for defense well before the fire travels that far.

Communication and logistics are major problems at a conflagration. There must be a central dispatch center for the mutual-aid area. Radio control is essential; therefore, there should be frequency compatibility. Tracking apparatus and personnel will be difficult at best, but that task is a primary consideration. Conflagrations present a subject area where lack of experience requires study and preparation, rather than on-the-job training.

Although it was reported that some of the spread of fire in Boston was against the wind (by radiation), this process did not happen at all in some of the other notable conflagrations. Both of the Chelsea conflagrations spread only in the direction of the wind, and so did the great Chicago fire of 1871, which burned for about 36 hours over an area four miles long but only two-thirds of a mile wide. It is widely known that the fire started in Patrick O'Leary's barn, but not so well known that O'Leary's house was never even scorched.

At the same time that fire was devastating Chicago, another fire wiped out Peshtigo, Wisconsin, with the largest death toll of any American fire, as 1,182 residents lost their lives. I believe that this simultaneous occurrence was more than mere coincidence and hereby advance a theory on atmospheric influences upon fire.

Peshtigo and Chicago are less than 200 miles apart. Their atmospheric conditions are similar at many times. The Peshtigo fire had been burning slowly in the woods for three weeks, and nobody worried about it until it suddenly gained in intensity and swept into town with such speed that most people couldn't escape. Why the sudden change?

On April 18, 1963, Wisconsin was hit by an astounding number of forest fires, brush fires, and grass fires. It usually takes atmospheric conditions two days to move from Wisconsin to the East Coast. Sure enough, on April 20, the East Coast, from northern Virginia to Massachusetts, was struck by the largest number of simultaneous fires ever. There were thousands of brush fires but also hundreds of building fires. The New York City fire department had its busiest day, with about 2,000 alarms, most of which were for structural fires, including 12 multiple alarms, and the largest industrial fire of the year took place in New Jersey. It was estimated that, during the afternoon of that day, more than 70 percent of all fire departments in a seven-state coastal area were fighting fires at the same time.

Yet, as at Chicago and Peshtigo, the next day was back to normal. It is said that all of these events were due to prolonged dry spells and high winds. The dry spell continued in Wisconsin and the East Coast; why didn't the fire-breeding conditions? High winds may spread fires, but they don't start them. I suspect, but have no scientific evidence, that on certain occasions there are atmospheric conditions, as yet unrecognized, that are favorable to fire. They may be submolecular or even subatomic in nature.

Conflagrations do not represent the only large-scale disasters that a fire department may have to face. There are railroad wrecks, pipeline explosions, flammable or poison gas leaks, and many other disasters that may call for great numbers of firefighters and equipment. Big cities can usually handle their own, but small towns may have to summon help. It is for this reason that the following checklist was prepared.

FIRE OFFICIALS OF DISASTER AREA

1. If you were not in the immediate vicinity of the disaster, how would you be notified of its occurrence?
2. What would be your first actions on learning of the disaster?
3. Could your department cope with a large-scale disaster or would it require assistance? How much? What type? From whom?
4. To whom would you communicate your need for assistance? How would you reach that person?
5. Does your department have the capability to communicate with other departments that would respond to the disaster?
6. If outside assistance is required, do you have formal mutual-aid agreements with adjacent jurisdictions?
7. Do any existing agreements spell out exactly what assistance would be provided if called for?
8. Who would coordinate activities at the scene of the disaster?
9. Would your coordinator have operational control of out-of-town forces providing aid? How would he or she communicate with them?
10. Does your compensation insurance provide coverage for out-of-town personnel providing aid?
11. Does your city or county have legal authority to pay the expenses of outside organizations that render assistance?
12. If you or your deputies should be injured in this disaster, who takes over to make the necessary decisions?

MUTUAL-AID PROVIDERS

1. What would be your first action on being advised of a disaster in an adjacent jurisdiction?
2. If called on for assistance, what help (personnel, equipment) could you immediately supply? For how long?
3. What would be your legal basis for supplying out-of-town assistance?
4. Have you legal authority to expend local tax dollars outside your area of jurisdiction? Must you be reimbursed for these expenditures?
5. Does your compensation insurance cover your personnel while giving aid outside your area of jurisdiction?
6. Who would have operational control of your personnel while they are giving aid?

7. Would you retain administrative control?
8. How would you communicate with your personnel at the disaster scene?
9. When you dispatch a large percentage of your personnel and equipment to aid in this disaster, are you, in turn, covered by other departments in the event of a disaster in your town?

15

The Everyday Fire

THIS CHAPTER covers the most common types of fires to which the fire service responds. The first—and smallest—are dwelling fires which, by far, account for the largest number of structural fires.

Fire in a dwelling involves very personal property, some of which may have strong sentimental value. Therefore, firefighters working at such a fire, whether it is in a one-family or multiple dwelling, should bear these facts in mind. Damage that would be tolerated in a well-insured place of business might be extremely painful to a householder. Little extra touches of consideration during forcible entry, salvage, and overhaul will go a long way to improving the firefighter's image.

No matter whether a dwelling fire is in a bedroom, kitchen, living room, or bathroom, an early examination above the fire is required to assure that no occupant has been overcome by smoke and that the fire is not extending. In a one- or two-family house of balloon-frame construction, the attic should get immediate attention. Fire tends to get into the side wall spaces and run quickly up into the attic where there is usually a lot of combustible surface (Figure 15.1).

When fire is discovered in a side wall, a bent nozzle should be inserted in the wall space and aimed upward. Due to gravity, water will run down after going up and thus hit fire that travels both ways.

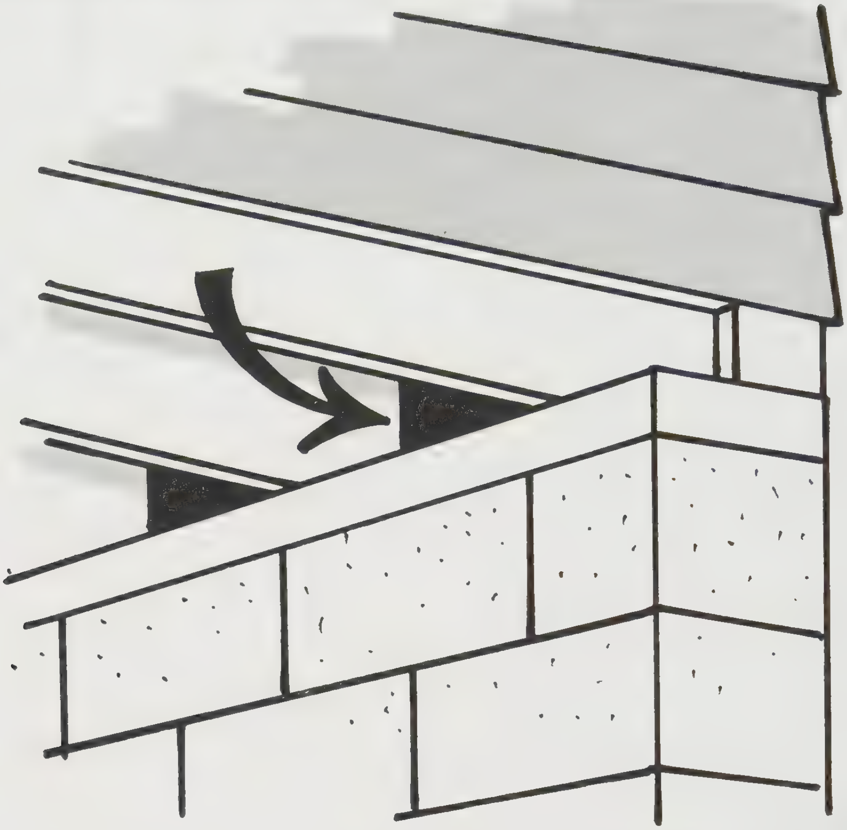


Figure 15.1. The arrow points to an opening through which a basement fire can travel to enter side walls and then upper floors and attic of a dwelling. Construction is of the balloon-frame type.

Figure 15.2. More fires occur in dwellings than in all other types of structures. Dwelling fires also account for the most deaths, with nighttime fires taking a particularly heavy toll.

Many dwelling fires occur in bedrooms, and the usual bedroom fire involves a mattress. Kapok or cotton mattresses give off a light-colored smoke, which is bitter to the taste and somewhat discomforting, but not a serious hazard or impediment. Foam rubber or polyurethane mattresses are quite different. The smoke from them is rather sweet but is very dark and dense, causing a serious soot problem distant from the fire. Both types of mattresses are easily extinguished with water. After a small sprinkling of two or three gallons of water, the mattress should be shoved out the nearest window and extinguished on the ground. The reason for this procedure is that it can be extinguished completely without water damage which might occur in a building. The reason for taking it out by way of a window is that mattresses taken through halls and down stairs may suddenly flare, causing increased damage and possible injury to firefighters. There is seldom a need to break windows when ventilating a bedroom fire. Opening them is sufficient in most cases and, in others where the room is fully involved, the fire itself breaks the window glass. In addition to a burning mattress, there may be involvement of wood bedsteads and dressers as well as paint on the walls. The brown color of the smoke is an indication of burning wood. + Non Metal Oxides

It should not be necessary to remove wood furniture. A bed can be quickly taken apart by a claw tool or some similar tool. To avoid burns, firefighters should not touch hot metal parts of the bed. Charred dressers can be examined, and burnt clothing removed and placed in a bathtub along with burnt clothing from closets.

If the fire is intense enough to warrant it, holes can be made in the ceiling to search for extension of the fire. Wood door and window casements may be opened for similar search.

If there is reason to believe that a fault in concealed electric wiring may be the cause, or if there is evidence that fire may have entered a side wall, such wall should be opened for examination. An examination should be made of the area above the fire before leaving the premises.

PLASTICS

The materials popularly known as plastics are more properly called "polymers." They have also been referred to as "frozen flammable liquids," which is a fairly apt description, considering that they are derived from petroleum. The process by which they are converted from monomers to polymers (hence the name) alters their molecular structure and in so doing changes the characteristic of most interest to firefighters: flammable liquids are not easily extinguished by water, but polymers are.

Polymers are available in a variety of compounds formulated for different end products. Some are rigid; some are flexible. They are fabricated into many forms for many purposes and are found in quantity in almost every type of occupancy.

The heat of combustion of most polymers is much higher than that of most natural materials such as wood, paper, and cloth: about 7,200 BTUs per pound for natural materials, and about twice that for common synthetic polymers. Most of these polymers ignite easily and, in addition to intense heat, also give off dense black smoke. Their frequent use in furniture as filling for mattresses, cushions, and upholstery leads to quick flashover, high temperatures, and heavy smoke when such contents of buildings are involved.

It is fortunate, however, that a sufficient application of water as either fog or straight stream will extinguish such fires quickly.

OIL BURNERS

Oil-burner fires are easily identified by the black, sweet-smelling smoke of burning fuel oil. They are essentially fuel-oil fires and, as such, can be extinguished with class B extinguishers or water spray.

Ventilation is important to channel the sooty smoke in the least harmful direction in order to keep smoke damage to a minimum.

The oil burner's electric motor should be shut off as soon as possible, and the valves at tank and burner closed.

CHIMNEY FIRES

Until about 1930, the most common type of fire was the chimney fire, because soot, accumulated on the inside of the chimney, contained large amounts of unburned carbon, which could ignite if it became hot enough. Then, with the replacement of wood- and coal-fired systems by oil burners, chimney fires became rare. The fuel-oil shortages of the 1970s led to a new interest in wood as a fuel, and its increased use led to a resurgence of chimney fires.

The most important action at a chimney fire is to make sure the fire hasn't extended from the chimney into adjacent combustible material—wood structural members, perhaps, or objects stored next to the chimney in the attic.

The extinguishment of the fire inside the chimney is usually done by taking a small hose line to the roof and applying a gentle spray down the chimney. Of course, this process can be messy and could possibly cause cracking of the flue liner if not done carefully—and, if it is done to a chimney serving a fireplace, the fireplace should be diked with salvage covers to prevent water running on to the floor.

An alternate method is to use a chain and brush arrangement, lowering and raising it to clean the chimney from the top. In this case, too, the fireplace should be protected to keep the falling soot out of the room.

One way of inspecting the inside of a chimney to see if the fire is still burning is to use a mirror at the bottom.

BASEMENT FIRES IN DWELLINGS

Basement fires can extend upward in dwellings in three ways. One is by way of the interior stairs, especially if the door at the top of the stairs is open. The second is by heating (or central air-conditioning) ducts which reach all parts of the house. The third is by way of the side walls. Some houses have a fourth avenue of fire travel: a laundry chute into the basement. When there is a fire in the basement, all of these vertical avenues should be checked. Oddly, basement fires often travel upward between the walls on the side opposite that where the fire started. The fire travels across the basement ceiling and up the opposite side.

Ventilation should be performed throughout the building, by opening all windows and doors, and, when present, attic louvers.

ATTIC FIRES

Some attics in dwellings are unfinished; others have a floor and sometimes rooms. The unfinished attic without a floor can be reached by a piercing nozzle thrust through the ceiling below. The spray from such a nozzle is usually quite successful in extinguishing a confined attic fire. In this type of unoccupied, unfinished attic, there is usually no need to ventilate other than by opening attic windows or louvers. A hole in the roof should not be necessary.

In the finished attic, however, the hose line will probably have to be brought into the attic in the face of much smoke and heat. If the attic is divided into rooms, the problem is compounded, and it is likely that a hole may have to be cut in the roof for ventilation to allow the advance of the hose line. A futile gesture often observed at attic fires is that of a stream directed on to the roof; it does no good and may retard ventilation.

MERCANTILE FIRES

Most fires in stores occur in a ground-floor store or the basement under it. If the premises are not sprinklered, a store fire can travel rapidly because it usually has so much to feed upon. Most stores contain large unbroken sales areas and small service areas in the rear. More often than not a fire starts in the rear area, although less frequently it is found in the front only, and still less often throughout the entire store. The ideal rate of flow should be provided for the entire store, because it may become fully involved after operations have commenced. Ventilation should be thorough, especially on the roof. If conditions warrant, the entire show window should be removed for ventilation and access. If there is a partition in the back of the show window, it, too, should be removed.

T Overhauling after a store fire can be tedious, especially if a large amount of stock has been involved. Remember that the stock is valuable, and that, if insurance is to be collected, an inventory may be necessary. Therefore, stock may be moved for examination but should not be left outside where it could be stolen or further damaged.

Store Basement Fires

Fires in store basements are among the most difficult to fight, and several of them have taken a high toll of firefighters' lives. Limited access is one of the problems with fires in the basements of stores. Usually there are no windows and only one or two stairways. Therefore hose lines have to be advanced under extremely adverse conditions until the stream can strike the fire. Breathing apparatus can protect against the smoke, but heat and lack of visibility are severe handicaps. Ventilation is difficult to achieve due to the absence of windows. Often the only upward path for smoke and heat is the stairway being used to advance hose lines.

Ventilation, however, should be started on arrival immediately upon ascertaining that a protecting hose line is in position and charged. Start at the bottom with the opening of any basement windows that may be present. The store should then be ventilated front and rear, and show windows broken out if conditions warrant it. In a multi-storied building, the roof and upper floors will probably have to be opened.

Frequently a large amount of stock is stored in the basement, which not only provides a heavy fuel load but also obstructs hose streams and makes hose line advancement difficult. Another danger is the utility entrance that is usually found in the basement. There is a likelihood of gas igniting when the heat of a basement fire melts the connections at the gas meter. It is essential, therefore, that gas service be shut off as soon as possible.

The floor joists of the store's floor are usually exposed and will burn readily. When they do, the floor loading in the store may be heavy enough to cause the floor in the area where the joists have burned to collapse. In some stores the fire will be able to enter the walls and travel vertically. In certain buildings, especially those which were erected at the same time, fire can travel horizontally at the level of the basement ceiling to an adjoining store.

The first step in combating a store basement fire should be to guard against upward extension. The interior stairway is the most vulnerable avenue, and a hose line should be placed at the top of it. Walls should be felt for signs of heat and water inserted if necessary. An aggressive attack should be attempted in the basement itself with a sufficiently large nozzle and hose; usually a 2½-inch line is needed. Its weight is not a great handicap, because it will be moved down and forward, not up a stairway, and there is no problem of water damage below the fire floor.

In extreme cases, two lines can advance together with one nozzle set on wide fog for protection against heat, and the other applying a solid or straight stream for reach and penetration. If there are two entrances, the use of opposing streams should be resisted for the reasons stated in earlier chapters. The entrance chosen should be that which will give the quickest or easiest access to the fire, as long as it will not assist fire extension.

If hose lines cannot be advanced sufficiently to extinguish the fire, then cellar nozzles must be inserted in holes cut in the floor or through windows if any are present. The sites of holes cut for cellar nozzles should be carefully chosen so that the water will strike the fire. If there is a hot spot on the floor, it is a good indicator of where to cut the hole. If, however, there is no hot spot, an estimate will have to be made.

High-piled stock and partitions may obstruct the stream from a cellar nozzle. When there is evidence that this obstacle is present (no reduction in heat or smoke), another hole should be cut and the nozzle moved. Before the new hole is cut, however, the nozzle should be raised and lowered a few times in an effort to get the stream to go past obstructing stock piles. Sometimes the reach of the stream, especially if a distributor nozzle is used, may not be enough to reach all of the fire, and a hole should be made in another location. Sometimes, two or more cellar nozzles may have to be used simultaenously.

Use of High-Expansion Foam

High-expansion foam has been tried successfully at some store basement fires. In some of them, this foam has provided total extinguishment. In others, it has enabled firefighers to enter the basement and complete extinguishment with hose streams. When it is used in a store basement, certain facts must be remembered. High-expansion foam will not go through walls or closed doors, and it will not reach a ceiling unless an opening is present there. It is slow to travel upward in wall spaces and should not be expected to overtake fire there. If it is not completely effective from one point of application, try another. Remember that it quite likely will extinguish a gas fire and that the gas supply must be shut off.

The overhauling of store fires often involves the handling of costly articles. The way in which they are treated can affect the amount of loss. Of course, articles which have already been ruined by heat will not matter, but many others can be salvaged. Water can be more damaging in a store than in a home. Wherever possible, the use of water should be avoided in overhaul, and dependence placed more on thorough examination of contents, moving them as necessary. The building should be overhauled with tools rather than water, by making the necessary openings for complete examination.

Provision should be made for protecting the premises after a fire during off-hours when the tenant is not present. If the building cannot be barricaded against theft, then a policeman or firefighter should remain to watch the premises until a representative of the occupant arrives.

TAXPAYER FIRES

A common type of mercantile building that presents problems in firefighting is the so-called taxpayer (Figure 15.3). The name derives from the reason that the building was erected. Somebody buys a piece of land in the hope that it will increase in value in the future, but, to offset the taxes on the property during the period of appreciation, the owner erects a building to provide rental income. Such buildings are not intended to last. They are built as cheaply as possible and consequently, from the fire protection standpoint, are full of flaws. Similar buildings are also called strip shopping centers (Figure 15.4).

Taxpayers are usually built as a row of stores, one story high, but sometimes two-story buildings are erected with stores on the ground floor and other occupancies above. Construction is usually poor. An uninterrupted cockloft frequently covers several stores. Some taxpayers have fire walls, but seldom between every store; where they are present, they are often inadequate. In some taxpayers there is a common basement that extends, like the common cockloft, under a row of stores. Storage space for each store is separated only by chicken wire or wood-slat partitions.

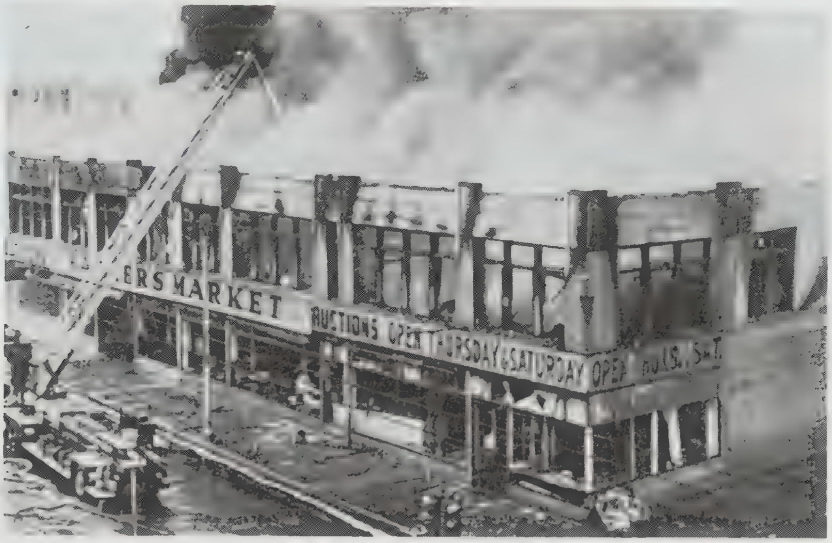


Figure 15.3. "Taxpayers" are usually built as a row of stores one story high with a common cockloft and frequently a common cellar. Fire walls, when present, are often inadequate and are rarely provided as one for each store. The two-story taxpayer shown is less common, but it shares most of the characteristics of the one-story type. When any building is beyond saving, heavy streams from any safe vantage point (even aimed through the roof) may be used to complete extinguishment, in what is known as the "surround and drown" technique, which is sometimes euphemistically termed "hydraulic overhauling."

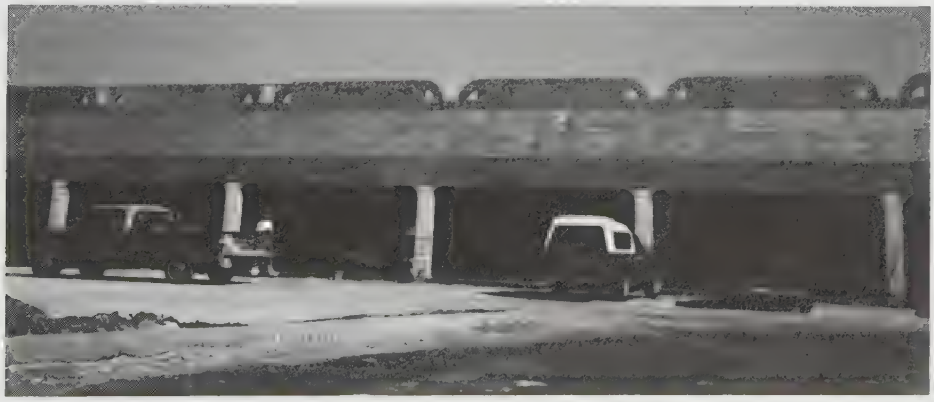


Figure 15.4. The strip shopping center is basically the same as a one-story taxpayer. This shopping center has a combined canopy and facade made of plywood, running without interruption for the entire length of the row; later, it was covered with tile and stucco.

Because of the type of construction, a fire originating in one store of a taxpayer has a good chance of spreading to others. If a fire starts in a basement, there is little to stop its horizontal progress. If it starts in a store, it can extend into the cockloft and, once there, can move horizontally with little or no resistance.

Ventilation at the roof is more important at a taxpayer fire than at most others. A large hole should be cut to draw the fire out and delay the horizontal travel. It is recommended that the hole be cut directly over the fire and that it should measure about 80 square feet, if practical. It is also advisable to get at least a small hole in the roof first, to prevent backdraft when the ceiling is opened up.

The key to success in this type of fire is to get ahead of the fire, which is done by getting hose lines into stores before the fire reaches them and getting ceilings down and water ready before the fire passes that point. Admittedly, it takes courage to open the ceiling in a store that is two stores away from the actual fire. Yet, if this decision is delayed too long, the fire may travel one store ahead of the firefighters until it reaches the end of the row. If there is a strong doubt of a fire's extension, look for warning signs before opening the ceiling. Such signs could be audible, in the form of crackling sounds, and visible, as discoloration or blistering of paint on the ceiling.

The two-story taxpayer provides double trouble. Fire can travel horizontally via the cockloft and the hanging ceilings in the stores. Vertical travel can occur by way of stairs and walls.

It is possible for some two-story taxpayers to present a life hazard involving many persons. The second-floor occupancies may include dancing schools, bowling alleys, restaurants, and other places where many people are gathered. In such cases, prompt laddering of the second floor may be essential to provide egress.

MULTIPLE-DWELLING FIRES

Multiple dwellings vary from city to city. Boston and other New England cities have "three-deckers," which are wood-frame, three-story buildings housing one family on each floor. They usually include an open rear porch on each floor and are separated from adjoining buildings by a narrow passageway. Chicago has its "three flats." These are similar to the three-decker in that they are three stories high, with one family per floor, and usually with rear porches on each floor. Most of them, however, are of brick wall and wood joist construction, although the back porch is of wood. Buildings similar to these two basic types are found with some variation in many cities across the nation.

Although the rear porches and their stairways provide a secondary means of egress for occupants and access for firefighters, they also present a hazard. Made of wood, the porches and stairs are combustible. Furthermore, it is common for the porches to be used as storage areas, thus providing more fuel sources. A fire starting on a rear porch has much to feed on, plus an unlimited supply of air because the porch is open. Therefore such fires can rapidly increase in intensity and size. When a strong wind is blowing, the fire will soon threaten the porches of the next building downwind through convection as well as radiation. The building upwind is susceptible to ignition by radiation. In some cases, the radiated heat has ignited porches on the rear of a building which is across a back yard from the fire building, a distance of about 50 feet.

The common procedure at a well-involved porch fire is to take the first line to the rear between the fire building and the one on the lee side of it. A second line is taken to the rear on the other side of the fire building, and both lines are used to protect the exposed buildings and knock down the main body of fire. Additional lines are taken by way of interior stairs, or ladders in the front, to each floor of the fire building to prevent or extinguish interior extension of the fire. It is recommended that the exterior lines be 2½-inch hose. The magnitude of the fire may require the additional volume and reach that this diameter provides.

Extension of Fires

It is not unusual for a fire starting in the interior of one of the apartments in these buildings to threaten the adjacent building. The exterior siding is frequently constructed of wood, or wood covered with an asphalt-base shingle which will melt and burn. Fire breaking out a window can quickly reach such fuel sources because the space between buildings is usually 15 feet or less. When a fire has extended to the next building before arrival of the first engine company, a complex problem confronts the officer in charge. If personnel are sufficient, lines should be advanced into both buildings simultaneously, but it might be well to use one of those lines to knock down the exterior fire before moving inside. When there are not sufficient personnel to stretch two lines at once, a decision will have to be made as to where to take the first line. It might be well to use it initially between the two buildings in order to extinguish as much fire as possible from one point before moving inside.

When a fire occurs within an apartment of a three-decker, fire departments well experienced in such fires take the first line directly to the fire by way of the interior stairway. This way is not only a direct route but, more important, will keep the fire from extending by way of the stairs. If the heat and smoke have banked down to the point where entrance to the apartment from the stairs is too difficult, another line can be taken in from the back porch while the stairway line stands by to protect the stairs. Prompt laddering at fires in these multiple dwellings is necessary, especially when the fire or smoke has rendered stairways impassable.

The Tenement

A type of multiple dwelling found in New York City and some of its environs is the "old law" tenement (Figure 15.5). There are still

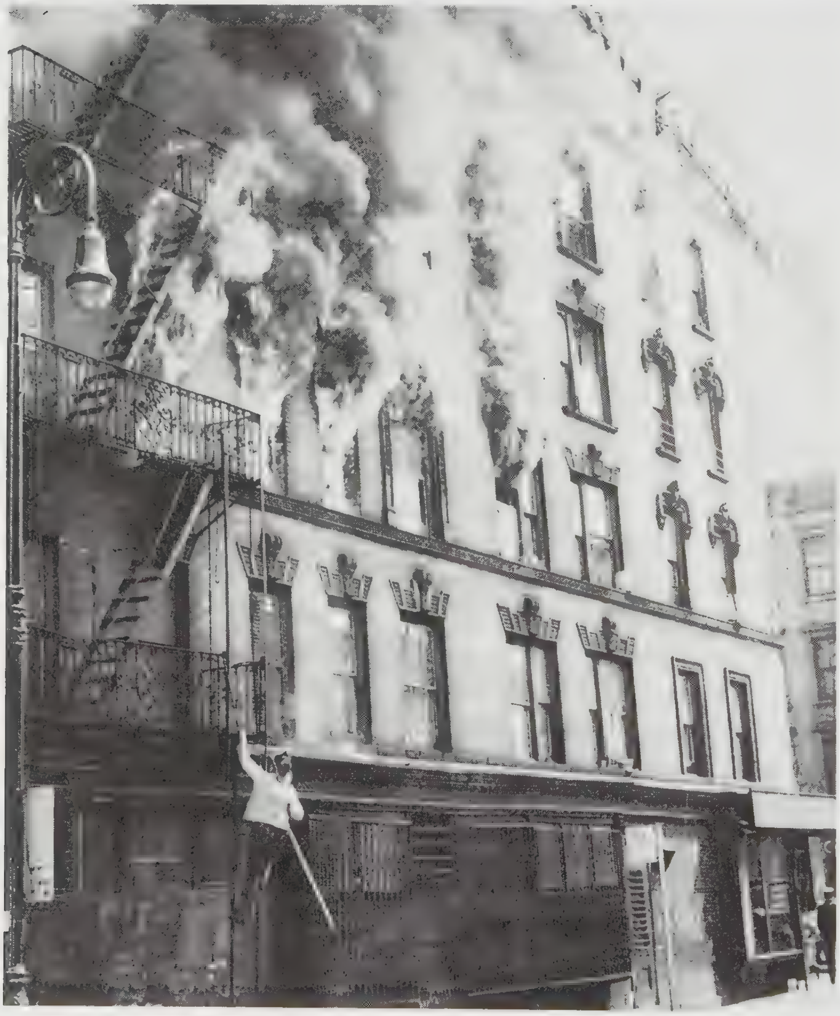


Figure 15.5. *This typical older apartment house (tenement) calls for prompt and thorough ventilation to extinguish fire and save lives. A ladder has already been raised here for roof ventilation. Firefighters have gained access to the windows at the right on the third, fourth, and fifth floors.*

thousands of these in New York City, even though they were built prior to 1901, when the multiple-dwelling law was changed to prohibit combustible stairways and doors and interior stairs to the cellar. Undoubtedly, similar buildings, or buildings with some of the same characteristics, can be found in many cities. The description following identifies them.

These structures are three to seven stories in height. Those above three stories usually have brick walls, but that is about their only incombustible part. The stairs, floors, and beams are all of wood. Doors are not only of wood, but often have a large glass panel or a glass transom. The stairs from the cellar lead up to a door that opens on the ground-floor hall. The width of the building is usually about 20 feet and the length varies from 50 to 90 feet. Occupancy can be from two to four families per floor. These buildings were usually erected in solid rows so that they line an entire square block without interruption, and there is no way to get to the rear yards except by going through a building.

Some of these buildings are divided into what are known as "railroad flats," so called because the rooms are one behind another like a train of cars, and the only way to one room is through another room. Usually there are two flats (apartments) on each floor. Another type has a private hall which serves all the rooms in the apartment. Sometimes this hall has to pass by another apartment and therefore is extremely long—90 feet being fairly common.

Most of these buildings have a light and air shaft between buildings, with windows opening on the shaft (Figure 15.6). All the shafts are open at the top, and some are open at the rear, but many are enclosed on all sides. In many cities, similar buildings exist in downtown mercantile areas, with stores on the ground floor and businesses or apartments on the upper floors.

Fire escapes serve each floor. If an apartment runs all the way from the front to the rear of the building, there is only one fire escape, usually located at the rear. If there are both front and rear apartments, there will be fire escapes on both the front and rear. Usually the law requires that at least one fire escape lead to the roof. Therefore, if it is apparent during size-up that the front escape doesn't reach the roof, then there must be another fire escape at the rear.

Fire problems in these buildings are numerous. A cellar fire can easily get up the stairs and throughout the building. How easily this fire extension occurs was shown by a pyromaniac in the district where I worked as a firefighter. He would go into a tenement cellar and, using the janitor's shovel, would shovel hot coals from the furnace on to the bottom of the cellar stairs. Several of the fires started in this fashion got all the way to the roof, by way of the stairs, in four-story buildings.

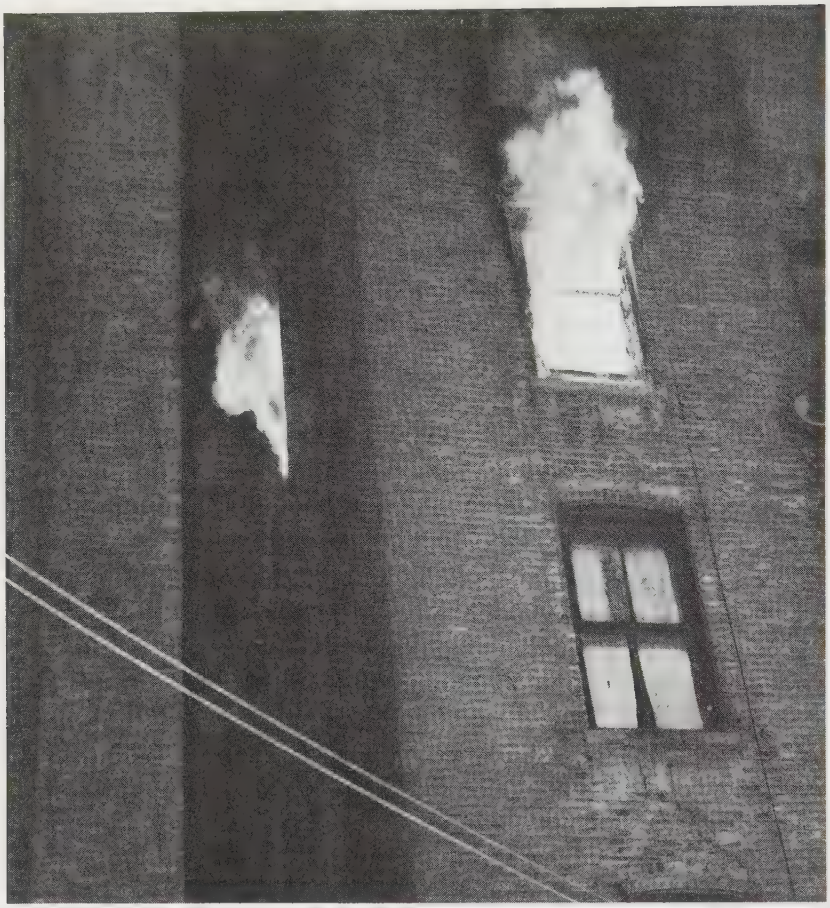


Figure 15.6. Light and air shafts (some completely enclosed between two buildings) can permit the extension of fire from one building to another, as in this photograph.

Usually, though, a fire starts within an apartment, but if the apartment door is left open by retreating tenants, or if it is glass-paneled, the fire will soon enter the stairway. The apartment doors offer little resistance to fire spread, and the fire soon communicates to several apartments.

The light and air shaft is another ready means of fire travel. Fire breaks out of an apartment window into the shaft and then enters other windows in the same or the adjoining building. All windows on the same level or higher than the original fire floor are vulnerable; it is common for fire to enter all of them.

Another means of vertical fire communication in this type of structure is around pipes—steam or water. Side wall travel is not common, but that should not be overlooked.

Horizontal travel—other than by the shaft—frequently occurs by way of the cockloft. In some cases, a common cockloft serving several buildings may be present. Usually, however, the cockloft has been subdivided by a brick wall, often not well enough to prevent fire speading through the wall because of defects, such as missing bricks or other openings.

Fire escapes provide good access for rescue, ventilation, and hose lines. The first line, however, should be taken to and up the interior stair to keep the fire from gaining possession of the stairway. Once fire gets into the stairway, it will probably enter the top-floor apartments and, if not stopped in time, will bank down to floors below the top floor.

Ventilation at the top of the stairs should be attempted immediately, without waiting for hose lines to be charged, in order to prevent the mushrooming of heat and smoke throughout the top floor. If much heat is traveling up the stairway, ignition may soon occur on the top story. Either a door, scuttle cover, or skylight will be found at the top of the stairs. The removal of this covering will ventilate the stairway, but other vertical arteries may exist, such as dumbwaiter and light shafts. They, too, should have covers removed to allow the escape of heat and the products of combustion. Prompt ventilation at the roof will greatly benefit any occupants trapped on the top floor—and even other floors above the fire. It will also enable firefighters to advance hose lines up the stairs.

Hose lines, other than the first, can be taken up fire escapes or ladders. The point of operation for the second line should be the top floor if the stairway is involved, or the floor above the fire if the fire has not entered the stairs. In all cases, the floor above the fire should be protected with a hose line, but whether it is the second, third, or fourth line depends upon whether or not the fire has entered the stairs, a shaft, or both. If fire is in a shaft between buildings, the second line should go into the exposed building to extinguish fire that may have entered there and to sweep the shaft to prevent further extension.

When the fire is in the stairway, the first line should be advanced up the stairway as rapidly as possible, passing fire in apartments on intermediate floors. Another line should follow this one to extinguish fire that has been passed and to protect the firefighters on the first line.

Sometimes when the front or rear walls of contiguous tenement buildings have a combustible surface such as wood or asphalt shingles, fire emanating from a window will travel up the surface and enter windows on floors above the fire, not only in the building of origin but also in adjacent buildings. An outside line provides protection against this kind of fire travel.

There is another type of multiple dwelling that has been built in great numbers in New York City from 1901 until the present and is found in similar form throughout the United States. In New York they were known as "new law" tenements to differentiate them from those built prior to 1901. A more common expression is "apartment house." These buildings are generally four to six stories in height, with a front varying from 35 to 60 feet and a depth of about 80 feet. They are usually occupied by four to six families on each floor. The interior stair is of incombustible material. The stairway and hallway walls are fire-resistive, as is the cellar ceiling. Other floors and joists are of wood. Doors to each apartment are also fire-resistive, and there is no interior stairway to the cellar. Pipe recesses and vertical columns, however, do provide means for vertical fire travel, and a cockloft covers the entire structure. There is secondary egress by either fire escape or rear stairway.

In this type of apartment house there is no great likelihood of a cellar fire extending upward, but I have seen it happen by way of steam pipes. Fire can burn through floors (other than the first floor), if it burns long enough. Fire is not supposed to travel by way of the stairs in these buildings, but I have seen cases where fire, coming out of the open doorway of an apartment, burned the wooden handrail of the stair banister, cracked the marble stair treads, and warped the metal fire doors on each apartment above the fire. Not only was the stairway impassable, but if the door to any apartment above the fire had been left ajar, fire would certainly have entered. Wall paint in the stairway is often a plentiful source of fuel for this type of fire. It will burn off in a few minutes, however.

During the 1920s, it was a common practice to erect these buildings in the form of a letter "H" with a cockloft extending uninterrupted over all portions of the structure. The cockloft is made vulnerable to the vertical travel of fire by way of dumbwaiter shafts, incinerator flues, elevator shafts, and vertical structural steel channel rails.

Fire escapes usually permit the escape of any occupants above the fire, but sometimes flame will burst out of a window and cut off the fire escape. In this case, ladders will have to be used for evacuation. Fire escapes do provide good hose line access to the fire floor and floors above it.

Incinerator Fires

A nuisance-type fire frequently occurs in this class of apartment house because of an incinerator used for the burning of refuse. The incinerator shaft is, in effect, a fire-resistive chimney with a door serving it on each floor. Trouble often occurs when the shaft becomes obstructed by an object too large to drop freely. This barrier keeps smoke from rising and forces it out on the floors below the blockage.

There is usually no hazard, but the tenants are discomforted by the smoke and call the fire department to clear it. A real hazard exists when the door to the incinerator chute is blocked open and heat as well as smoke can issue through the opening.

Some apartment houses have incinerators directly at the bottom of the chute, while others have a separate room at the bottom from which the refuse can be shoveled before incineration. In the first case, smoke and heat are intended to go up the chute; in the second, they are not.

Another type of garbage disposal uses a compactor. In this method, refuse is dropped down a chute into a machine which packs it into a cube. The shaft for the compactor, like the indirect incinerator, is not designed for burning. It presents a serious problem to firefighters when rubbish within it ignites.

Trash chute fires have caused the deaths of tenants on upper floors of apartment houses. In these cases, the fire originated in trash accumulations in compactor chutes. In one case, the fire started at the bottom and the heat traveled up the chute (convection) and reached one of the upper floors, where a chute door was missing. In another case, there were accumulations not only at the bottom but on some intermediate floors. While firefighters were working in the basement, fire got out of the chute on one of the higher floors. At any fire involving a vertical artery, search should start at the top of it as soon as possible and work down. A hose line should be taken above the fire and water put into the chute as needed. All trash must be removed to make sure that extinguishment is complete, and the trash must be removed from the building because it may rekindle.

Chute fires call for the following steps: Ventilate at the top of the chute at the roof, the top floor, and any other floor as needed to remove smoke; examine each floor for possibility of fire extension; reassure tenants; extinguish fire; and remove obstructions throughout the chute.

The cockloft space, where the chute passes through to the roof, requires examination to ensure that the fire has not extended into it. This can be done without damage by feeling the roof for heat and listening for the crackling of fire.

Basement Fires

Building codes generally prohibit the use of basement stairs that lead to interior halls of an apartment building and require that the basement ceiling be fire-resistive. This isolation of the basement is an advantage because it is used for the storage of all sorts of combustible articles. Each tenant has a cubicle, with walls of chicken wire or wood

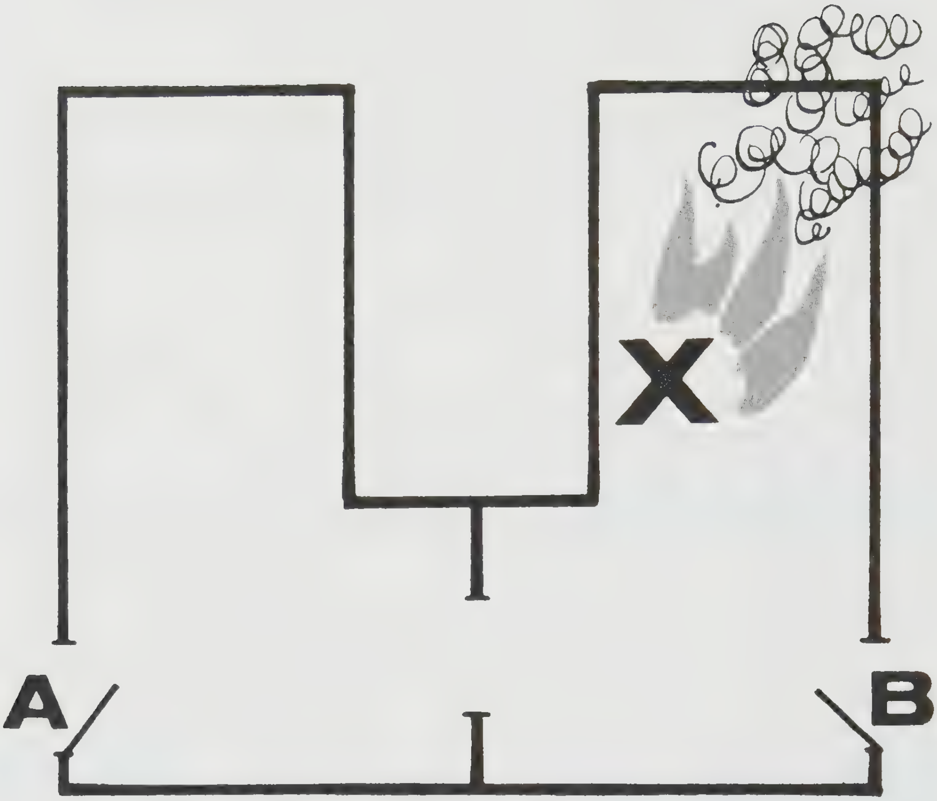


Figure 15.7. *A fire in a basement of a large apartment house calls for a judicious selection of entrance for hose lines. If the fire were at X, then entrance at B would offer a shorter and less punishing route to it for the firefighters. Entrance at A might still have to be considered if the fire were severe.*

slats, for the storage of excess furniture and other articles that are not used frequently. Consequently the total contents of the basement include a variety of combustible items. Flammable liquids such as gasoline, charcoal lighter, paints, and thinners are fairly common, as are such solid materials as rubber tires.

Apartment basements are usually large and undivided, and, with the large amount of fuel present, a sizeable fire can develop. The distance between entrances can mean a long trip to get the nozzle of a hose line within striking distance of the fire. In most of these buildings the basement entrance leads directly to an outside passageway, and entering the basement does not involve going down a flight of stairs (Figure 15.7). This arrangement is a distinct advantage, but the problem is choosing the best entrance. These basements are usually designed so that several turns have to be made in traveling through them. The route with the fewest turns and the shortest distance should be chosen. It is better to wait a minute and select the best entrance than to enter quickly at a point which may be more easily reached from the outside, but which could prove to be the worst once inside.

Another advantage of this type of basement over that of the older tenement is the presence of windows. It is not that these windows afford an access point for firefighting, but they can give some much-needed ventilation. The ventilation area they afford is tiny compared to the volume of the basement, but it is about all that there is available other than the doorways.

Although the likelihood of a basement fire getting through to the first floor is not great, vertical travel in such buildings can occur—from a fire on any floor—by way of dumbwaiter shafts and poorly stopped pipe chases. Another avenue of vertical travel found in some—but not in all—of these structures is by way of vertical steel structural members which are H-shaped and up to 30 feet long. The channels provided by the shape of such columns provide a flue for the ascent of heat and a chute for the descent of hot embers.

Cockloft Fires

Cocklofts about three feet deep usually cover these buildings. In some of them, the cockloft is subdivided by fire walls, but their presence cannot be taken for granted. In addition, such walls may have faults caused by poor workmanship or the ravages of time. Furthermore, a cockloft fire that burns through a roof can cross the low parapets formed by the walls and ignite the combustible roof on the other side.

Such roofs are not difficult to cut through, however, and cellar pipes or distributors can be used. Cellar pipes which project a stream for a distance provide greater coverage than a distributor. The distributor, however, can be left in place while the firefighers go elsewhere for reasons of safety or to perform other duties. Moreover, the finely divided stream from a distributor is more likely to turn into steam—a distinct advantage in the confined space of a cockloft. It would probably be well to try the distributor or fog pipe first and then follow quickly with a straight-stream pipe.

The location of any opening made in a roof over a large cockloft, whether it be for water access or ventilation, should be carefully selected with the safety of the firefighter in mind. For fires within apartments, the tactics are generally the same as those previously described for the older multiple dwellings.

GARDEN APARTMENTS

In the 1940s, a type of multiple dwelling appeared which was called the "garden apartment" because it was surrounded by grass instead of asphalt and concrete. This type of structure was set considerably back from the nearest street and, in many cases, from the nearest hydrant. Although some are of fire-resistive construction, most garden apartments are built to burn. The buildings are two, three, and sometimes four stories in height and vary in dimensions from 25 × 60 feet to 40 × 100 feet, depending upon the building code used. They are commonly constructed with wood studs, wood floor joists, plywood floors, plywood sheathing, and a plywood roof. Thus we find a lumber yard, rearranged to give more combustible surface of wood than would be found when it was stored for sale. Many of these structures have wood truss roofs and floors, too, which are subject to collapse (Figure 15.8).

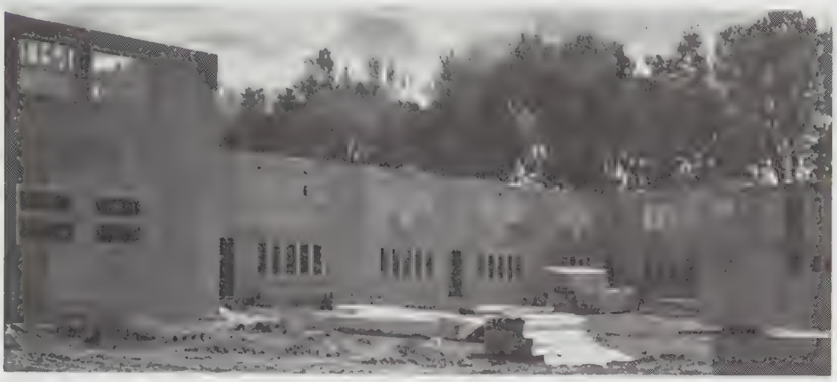
Most building codes today restrict the area allowed between fire walls in garden apartments, but some do not require roof parapets of sufficient height (three feet) to prevent horizontal fire travel along the roof.

Many of these apartments have balconies, and some balconies have floors of wood that permit rapid fire travel. Fire can also travel up interior stairs and through the wall spaces between studs—frequently with amazing speed. For instance, when I was director in Prince Georges County, fire occurred late one night in the living room of an apartment. The tenant called in the alarm from the room in which the fire originated. Five minutes later, according to a reliable 24-hour tape recorder, the first-arriving officer reported fire showing above the roof. Three persons died on the floor above the apartment of origin, of carbon monoxide inhalation, although firefighters reached them about 15 minutes after receipt of the alarm. Although it is probable that the toxic fumes reached the victims by way of wall spaces and through the floor, the balcony was badly burned from the fire below, and the windows opening on it were broken out by the heat from the outside.

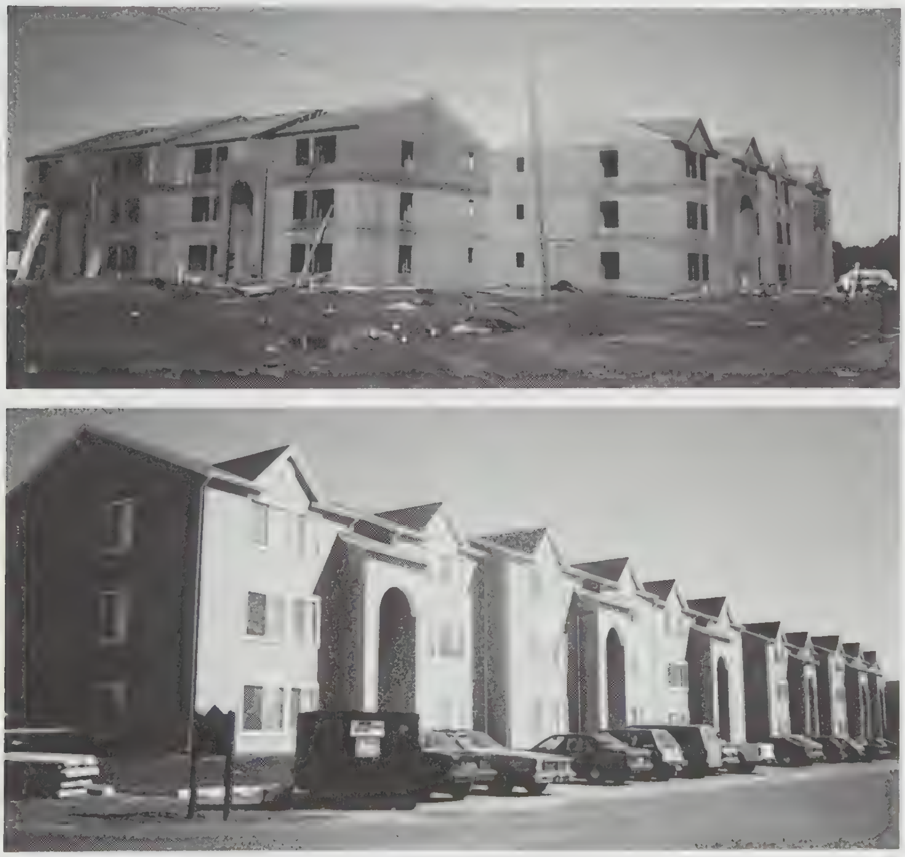
One of the hazards of many garden apartments is the large picture window or sliding doors, which usually open on to a balcony. This arrangement provides an abnormally large vent area when fire breaks through it. The amount of heat and flame escaping is great enough to enter windows above. Sometimes fire can enter the cockloft by way of combustible roof soffits.

Care should be taken in approaching the fire from a balcony. I know of one case where three firefighters stepped from a ladder on to

Figure 15.8. *These photographs show 25 years of progress in the construction of garden apartments.*



A. These garden apartments shown under construction are in effect a lumber yard placed on edge. The building was eventually covered by brick veneer, which does little to stop it from becoming a "quick burner."



B and C. *The garden apartments shown in these photographs were built 25 years after those shown in the first photograph. Both have plywood walls and roof, but the earlier one has roof rafters and floor joists, while the newer has roof trusses and floor trusses—both prone to early collapse. When covered with a stucco or vinyl veneer, however, they look quite substantial.*

the balcony just as the fire broke out through its large plate glass door. They were forced to jump off the balcony to avoid being burned.

Stairways are usually incombustible but would be impassable if much heat and smoke were issuing through an open door into the stairway. In such cases, ladders may have to be used for evacuation and to get above the fire. Ladders should be raised to all floors where people may be. An effort should be made to discover if fire has entered the cockloft and how far it could travel.

The off-street characteristics of garden apartments increase the difficulty of combating fires. Often, water mains do not provide sufficient flow, and hydrants are badly spaced. Pre-fire planning will disclose whether or not the ideal rate of flow can be achieved. Plans should be made for situations where the ideal rate of flow, personnel requirements, and pump requirements are not met by first-alarm companies.

Ladders may have to be carried and hose lines stretched by hand at many of these off-street situations. Parked automobilies may interfere with the placement of ladders and pumpers.

What was said of the basement storage areas in apartments also applies exactly in garden apartments. The tactics applied in basement fires—in fact, at fires in all parts of both types of structures—should be similar.

Many of today's garden apartments will be the slums of the future. Fire departments should plan for a considerably increased number of fires in this type of dwelling.

FACTORY FIRES

Factory buildings vary considerably because manufacturing processes differ widely, but one of the most common types of buildings in cities is the tenant factory or "loft building." This non-fire-resistive type is usually of brick wall and wood joist construction, from four to six stories in height. Fronts vary from about 25 to 60 feet, and depth varies from about 40 to 200 feet—in the latter case usually fronting on two streets.

There is usually one factory per floor, but in some buildings two tenants occupy each floor. Although there is a tendency for manufacturers of similar products, such as clothing, to congregate in one building, it is quite common to find several completely unrelated products being manufactured in the same building.

The potential for a fast-spreading fire exists in many of these occupancies. Large amounts of combustible goods and products are stored and, in some cases, processes involve the use of heat or flame. Building occupancy is heavy, and it was in one of them that the tragic Triangle Shirtwaist factory fire occurred in New York in 1911, which took a toll of 145 lives. Nearly all of those killed were girls working on the same floor.

The older type of factory buildings have open stairs and unprotected shafts. In some, even the elevator shafts are open, and large skylights may be found on each floor, one under the other, to let daylight down from above. It is no wonder, then, that fires in these buildings have to be hit hard and fast. The building will soon be lost if a heavy attack is not mounted quickly. Hand lines require good range and adequate volume. Streams may have to reach 100 feet or more, and the required flow rate may be as high as 800 gpm per story. The nozzle size which has been found most suitable is the 1¼-inch tip which flows about 300 gpm at 42 psi nozzle pressure. This nozzle gives a good stream of good range which can extinguish a sizeable amount of fire about a hundred feet from the nozzle; it is not too difficult to handle. The nozzle reaction is not quite 100 pounds.

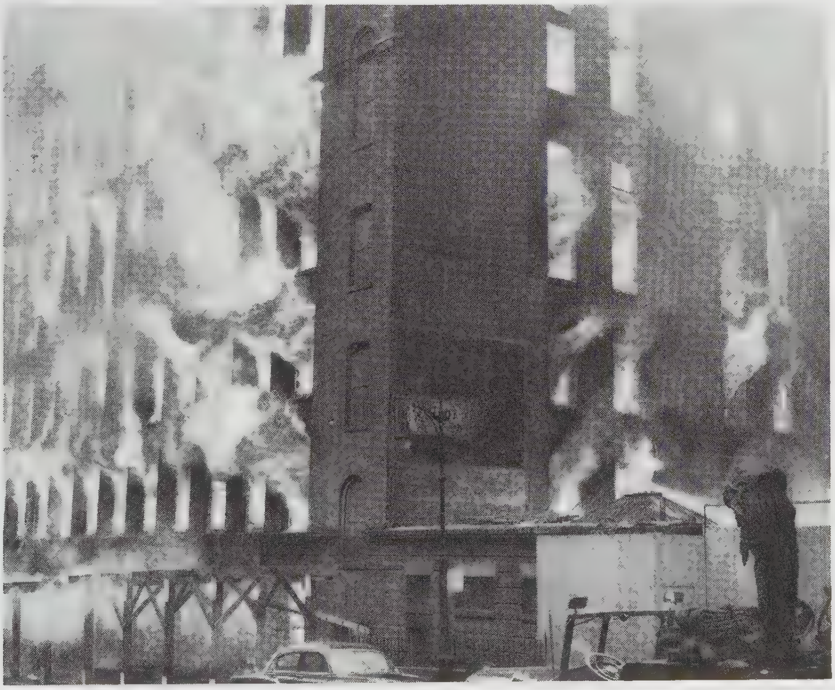


Figure 15.9. *Old multi-storied brick and wood joist factories and warehouses burn rapidly. This picture was taken about two minutes after the arrival of the first-due engine company. Note that the well-constructed stairwell is still not involved.*

Deck pipes usually come into play at loft fires and are often used for a quick knockdown and to prevent fire lapping out from front windows and into those above. When hand lines are used, however, they should not be sent in on the same floor that the deck-pipe stream enters. The deck-pipe stream can also be used on upper floors until a tower, elevating platform, or ladder pipe can get into operation. Furthermore, it can be used to protect companies working on fire escapes above the fire.

The first line at a loft building fire should be taken up the main stairway. Any additional lines required should follow the first or be taken up fire escapes. It is essential that a line or lines be taken in on the floor above the fire as soon as possible. This measure prevents upward extension of fire and permits this floor to be ventilated quickly and thoroughly so that any upward extension can be discovered.

Most factory buildings of any size have a standpipe, and it should be used unless the fire is on a lower floor where a hand stretch would be quicker. When the standpipe is used, it is essential to feed the system as soon as possible with a line from a pumper. Therefore, the first line should go into the standpipe siamese. Even if the building has a wet standpipe system, the pressure and volume are probably insufficient for the heavy streams needed. When taking hose to be used from the standpipe within a building, the floor area must be considered; three lengths of hose may be needed. If a sprinkler system is present, another line should be connected to the sprinkler siamese and the system fed an adequate volume of water. Care should be taken to make sure the proper siamese connections are selected. (See the material on sprinklers and standpipes.)

Ventilation should be thorough on the roof, the fire floor, and all stories in between. Usually the roof is within reach of aerial ladders, and nearly always there is a fire escape which goes to the roof.

At well-advanced loft fires, good vantage points for outside streams can often be found in other buildings across a street or an alley. Sometimes these buildings have standpipes which can be used (Figure 15.10). I once responded with a third-alarm engine company and used only three lengths of hose. We connected our line to a standpipe in the building to the rear of the fire and operated the nozzle there from a window, directing the stream into the fire building 20 feet away. This case illustrates one reason why 2½-inch outlets on standpipes are desirable.

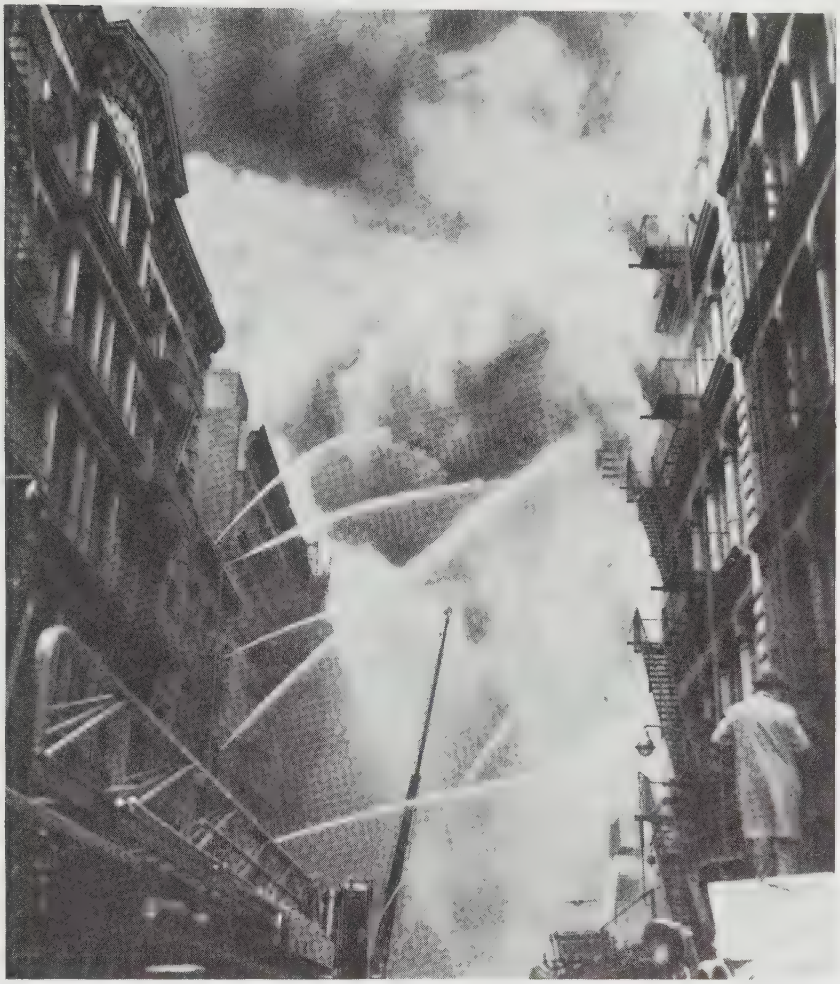


Figure 15.10. *Tenant factories (loft buildings) present a variety of hazards to the firefighter, and if fire in them is not knocked down quickly, an exterior attack must be used. Buildings across a narrow street afford vantage points for hose lines, as do buildings at the rear.*

Special Problems

Heat can be a problem in a fire-resistive loft building, much more than it would be with the same amount of fire in a building of ordinary construction. Fire-resistive construction contains heat like an oven. Ventilation is necessary to relieve the pent-up heat or the firefighters on the first hose lines will find advancement very difficult. Some cooling can be had by sweeping the stream around, but quite often there are partitions, enclosing the entrance from the stairs, that will obstruct the stream. Often the fire itself is in an area shielded by partitions, which heat can get around but water can't. Sometimes ladder company members can make a quick dash to windows on the fire floor and break them. More often they will have to go to the floor above and ventilate the fire floor by breaking its windows from above.

The second-due ladder company and an engine company with a hose line should go to the fire floor by way of the rear fire escape or second stairway. The ladder company forces entry and ventilates at that point, and the engine company gets ready to advance. If the first line can't advance, it should be backed out and this second line moved in. Often the second line gets a better shot at the fire than the first.

There is little likelihood of collapse in the fire-resistive type of loft building, but the non-fire-resistive factories have a long record of structural failure under fire conditions. It is in this type of building that the old rule of thumb applies: If more than two floors are well involved with fire, collapse may occur.

Factories other than tenant factories offer to the firefighter a challenging array of processes—some quite dangerous—and often house dangerous and highly flammable materials. Pre-fire planning is necessary to gain familiarity with what these hazards are and how to cope with them. It is also advisable to learn in advance what factory personnel can be relied on for correct information and advice during a fire. This help can be very important where the processes are complicated and materials hazardous.

16

Special-Problem Fires

THE EVERYDAY fires we have discussed account for the vast majority of all fires that occur. There are others that are special because they happen infrequently, they are found in an unexpected location, or they involve materials that are not commonly encountered. Vinyl chloride in a tank car is certainly a special-problem fire, as is a manhole that is belching smoke and flame. New products and new types of construction would also be on our list. We just don't know how any of these behaves under fire conditions until a few fires have occurred in them. Sometimes this experience is gained expensively—or even tragically.

By the very nature of the position, every fire chief should be aware of the more common special fires and how to combat them, but new products and processes are constantly coming into existence. The best way to find out about them is to read all the fire service literature available—regularly and frequently.

There are some special-problem fires that have been around for a long time in certain sections of the country, but which are now new to other sections. High-rise building fires come readily to mind.

HIGH-RISE BUILDINGS

High-rise building fire problems have increased in recent years as this type of structure, which was once confined to a handful of large

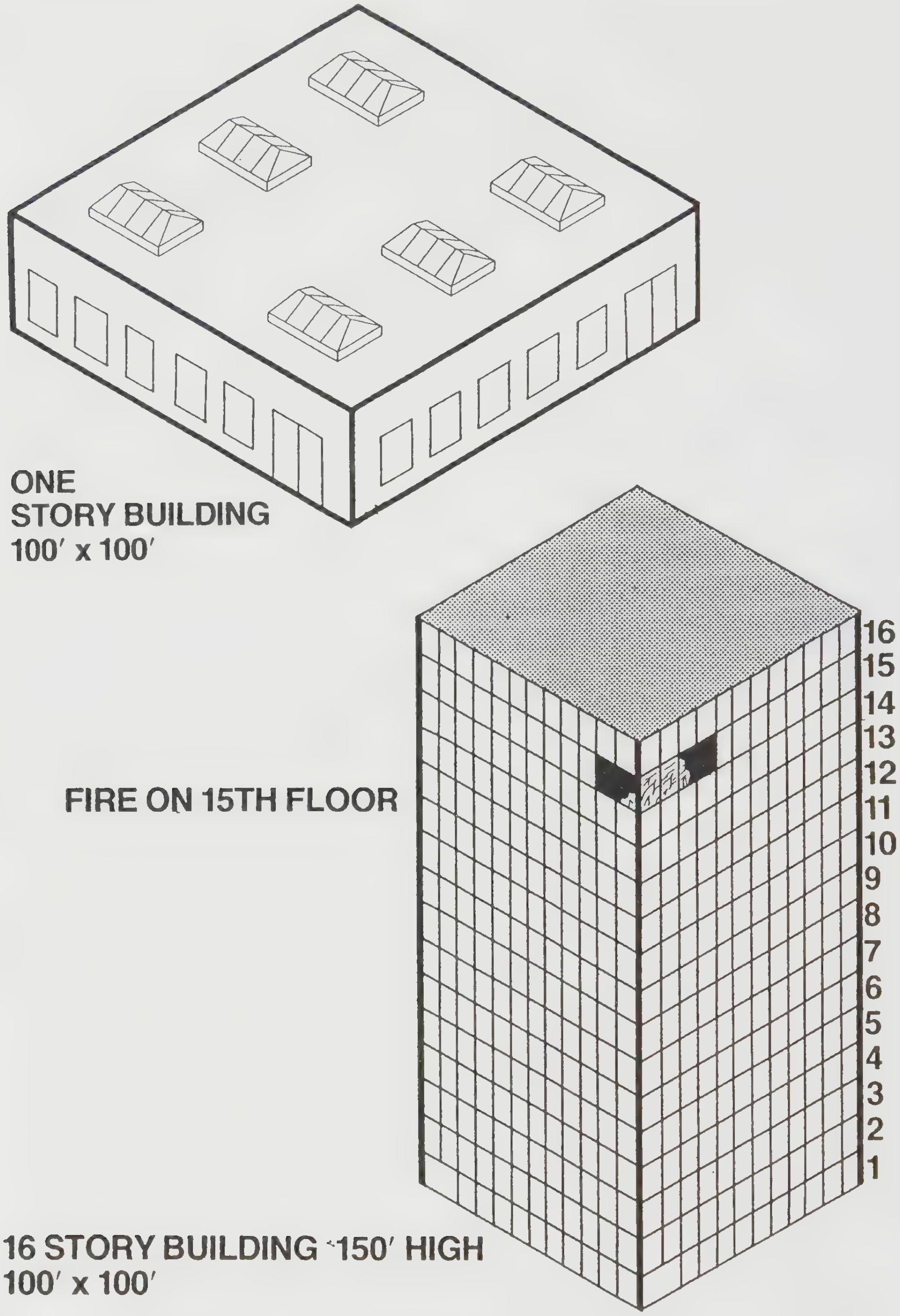

ONE
STORY BUILDING
100′ x 100′
FIRE ON 15TH FLOOR
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
16 STORY BUILDING 150′ HIGH
100′ x 100′

Figure 16.1. A and B. *The problems of high-rise firefighting can be easily seen in these illustrations. A large, one-story building can house a serious fire, but it gives advantages not available in a high-rise: the roof and windows can be reached for ventilation, and the fire floor is readily accessible from the outside. In the high-rise, however, the roof and windows may be inaccessible, and the fire attack must be launched from an interior stairway. Apparatus and equipment that are valuable at other fires may be of little use at a high-rise, and the tactical options are limited.*

cities, has made its appearance in a number of smaller communities. As is normally the case when an unfamiliar problem arises, there is some apprehension. Also, efforts to cope with the problem tend to be groping because they are not founded on firsthand experience. Consequently, mistakes should be expected. One way of lessening the mistakes is to learn from the experience of others.

There are practical methods used by fire departments experienced in firefighting problems peculiar to high-rise buildings. Tall buildings must have standpipes if fires are to be fought successfully, and firefighters must be trained in the ways to take best advantage of these standpipes. The stretching of hose lines to fires high above the street and the prompt provision of an adequate water supply with a good working pressure are among the operations that must be learned when a high-rise building comes to town. These buildings also bring problems of ventilation and communications, which will be discussed later. The use of elevators and the dangers associated with them under fire conditions also will be explained.

Although it is rapidly becoming more widespread, the high-rise fire problem is far from new. The first important high-rise fire was in New York City in 1898—the precursor of thousands of such fires fought high above New York's streets.

Definition of High-Rise

So that there may be a clear understanding, let us attempt to arrive at a satisfactory definition of the term "high-rise." It is suggested that we consider a building to be high-rise if its roof is above

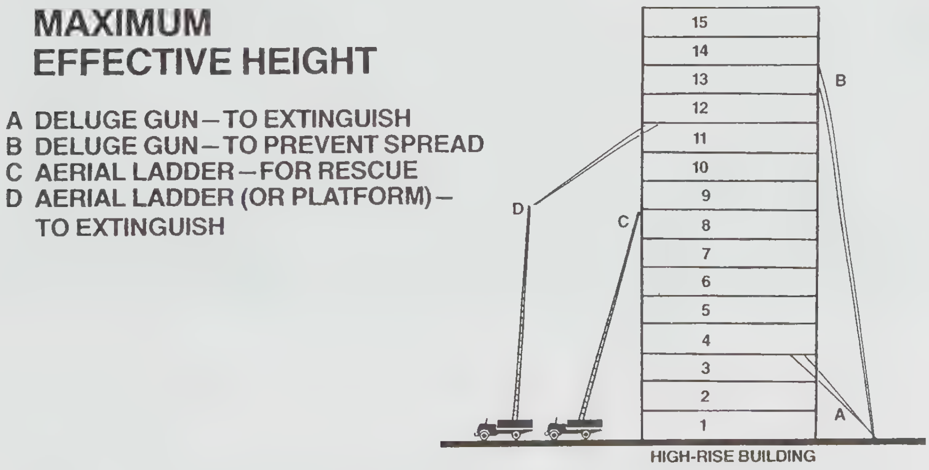

MAXIMUM
EFFECTIVE HEIGHT
A DELUGE GUN—TO EXTINGUISH
B DELUGE GUN—TO PREVENT SPREAD
C AERIAL LADDER—FOR RESCUE
D AERIAL LADDER (OR PLATFORM)—TO EXTINGUISH
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
A
B
C
D
HIGH-RISE BUILDING

Figure 16.2. The accessibility of the fire varies inversely with its height. Outside operations have definite height limits and become useless when these limits are exceeded.

the reach of a 100-foot aerial ladder and its topmost windows are too high for effective penetration of outside streams. Buildings more than 100 feet high generally fit this category (Figure 16.2).

Some buildings less than 100 feet high may present the same problems of exterior approach because of location rather than height. These are buildings set back from streets or otherwise located so that their upper portions are beyond the reach of aerials. Although they are not high-rise buildings, fire in them may call for the tactics needed at high-rise fires.

High-rise buildings have several features which could be considered favorable from the fire protection standpoint and others which can be handicaps and hazards to the firefighting force. Standpipes are a big asset, as is the fact that such buildings are generally of fire-resistive construction, which minimizes the spread of fire, especially from floor to floor. Structural collapse is not at all likely. Occupancies are usually offices or living quarters, thus presenting a fairly light fuel load. That the life hazard is not severe is indicated by a favorable life loss record. Occupants above the fire are usually safe from the spread of fire, but not always safe from smoke.

The vulnerability to smoke is proportional to the number of design faults, such as unprotected vertical arteries, ventilation ducts, central air-conditioning ducts, and the like. Ventilation ducts and utility shafts were responsible for carrying smoke to upper floors in several hotels where many persons died (Figure 16.3).

In addition, there are several characteristics of high-rise structures which are not faults but present physical problems to the firefighter.

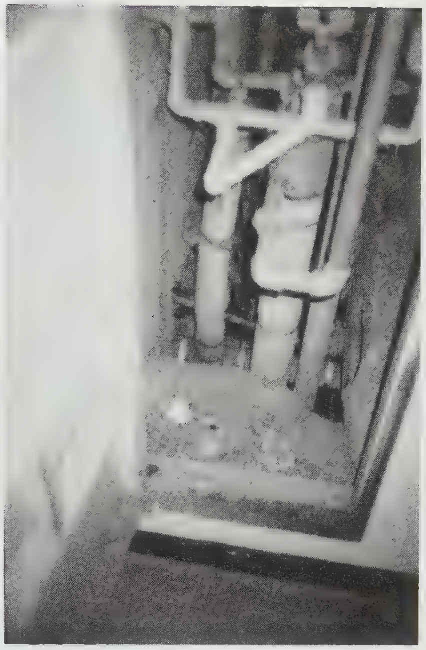
The first of these is height. The fire may be so high as to render aerial ladder rescue impossible and restrict access to the fire to interior means. Height can preclude the use of heavy streams and limit the rate at which water can be applied. Height sometimes makes roof ventilation difficult or impossible.

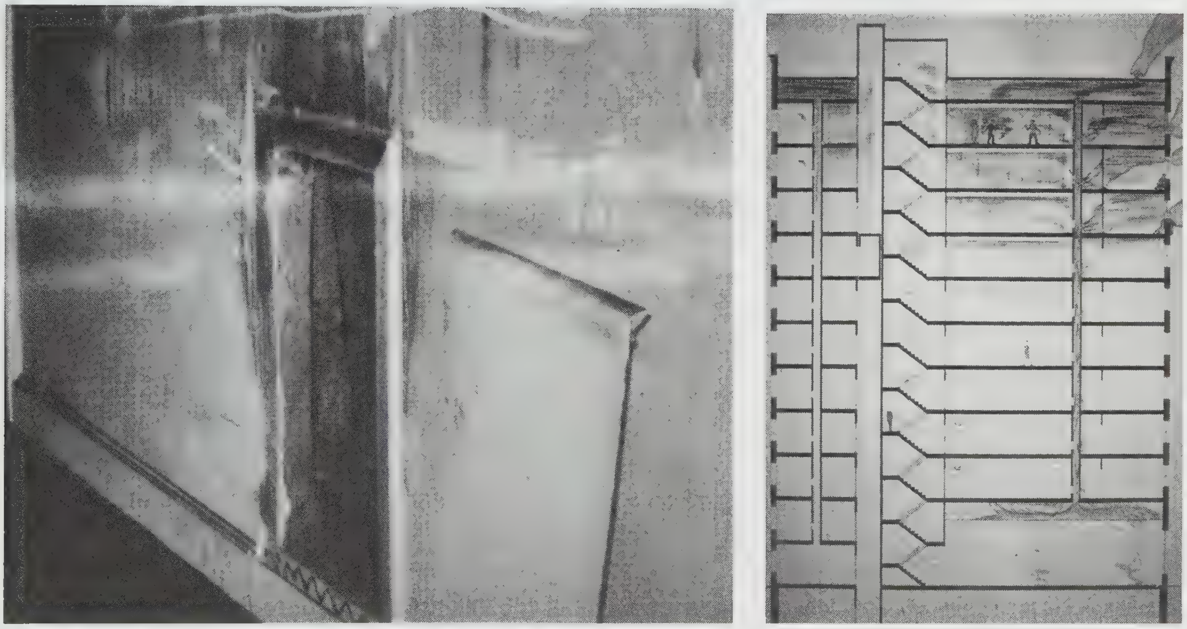
Fire-resistive construction, although a boon in one respect, can retain heat to the point where the fire floor will be virtually an oven. The high temperature hampers effective firefighting and takes a toll of firefighters. The intense heat can also cause the spalling of concrete from the ceiling, creating a danger to firefighters beneath.

Egress for large numbers of occupants is slow because of the distances to and down stairways, and also because many will try to use elevators, which have limited capacity. The use of elevators by occupants seeking escape (or sometimes just using the elevators normally) makes it difficult for firefighters to reach the fire by elevator.

Although building codes very from state to state and city to city, nearly all require high-rise buildings to be of fire-resistive con-

Figure 16.3.
A. *High-rise buildings have vertical shafts for utility pipes and wires. This illustration shows gaps in the floor, which will allow the upward travel of smoke and heat.*





B. *Utility shafts have service openings on every story. The doors or covers on these openings may not fit tightly enough to keep smoke from entering the corridor in dangerous quantity.*
C. When hot smoke from a fire on a lower story enters a utility shaft, it may rise quickly to the top and bank down, pushing into the hallway on stories where the shaft openings are not tightly covered. Bathroom ventilation ducts in hotels and apartment buildings will convey smoke in a similar manner, causing a severe life hazard, especially on the upper floors.

struction. Generally, this requirement means columns, girders, and floors with at least three-hour resistance to fire and enclosures for elevator and stair shafts with at least a two-hour rating.

Wood partitions are sometimes allowed, and in some cases wood stud partitions are permitted. Wood is allowed also for finished floors, baseboards, and trim, and some codes permit combustible accoustical tile ceilings. Therefore, although the structure will withstand fire, it can contain a fair amount of fuel even when empty of contents.

There is little likelihood of fire causing collapse of such a structure. Normally, the fuel load will not be sufficient to overcome the fire resistance of the structural members, which may be protected steel or reinforced concrete columns and girders. Reinforced concrete is commonly used in buildings up to 20 stories in height. Buildings beyond that height are usually of steel skeleton construction, as are many under 20 stories.

Possibility of Spalling

Reinforced concrete has a good resistance to fire, although when subjected to sudden uneven heating or cooling during a fire, portions of surfaces may separate and fall. This process is called spalling.

Structural steel should be protected with suitable fire-resistive coverings because the steel itself is not very fire-resistant; when heated above 1,000°F, it loses strength rapidly and expands considerably. Adequate protection for steel can be one of several approved coverings: concrete, vermiculite plaster on wire lath, gypsum block, and so on.

Fire Spread via Windows

Auto Exposure

Most building codes require fireproof window assemblies glazed with wire glass when the windows are close to the lot line or a narrow alley or court. This rule, of course, is to prevent entry of fire from an external source, such as an intense fire in a nearby building, but the protection of this feature is frequently nullified by the use of window air-conditioners or by merely leaving the window open.

The location of most high-rise structures—especially those recently erected—usually does not require many of the windows to be fire-resistive. Therefore, fire may spread vertically by breaking out through windows into the windows above. There have been many instances where fire traveled in this manner, in some cases for several floors. Recently, this problem has been intensified by the use of floor-to-ceiling windows, some of which leave as little as 18 inches between the top of one window and the bottom of the one above it.

Experiments in Japan have led to a requirement there that this space be at least four feet. Even that distance should not be considered absolutely safe; there have been fires which communicated through windows with greater vertical separation than that.

Stair and elevator shafts are usually well protected. Most codes require that they have at least a two-hour rating. The record of fire travel by way of such shafts indicates that although intense heat may go through an open door into a shaft and travel vertically through it, rarely will fire enter a floor from the shaft. (It could, however, in the very unlikely event of another door being kept open higher in the same shaft.)

Smoke can travel vertically through shafts to great heights and has proved lethal many floors above a fire. At a hotel fire in New York City, two men were killed by smoke 12 stories above a fire confined to a convention display area on the sixth floor.

Deadly smoke rises high. The smoke that killed two firemen on the twenty-second (topmost) floor of the former Times Tower in New York City came from a sub-basement fire two stories below ground level. At the same fire, smoke killed a building employee in an elevator, indicating that much of the smoke must have traveled upward through elevator shafts. Also, it is not unusual for smoke to make an ordinary enclosed stair shaft impassable, which is why two widely separated stairways are needed and also is the reason for fire towers and "Philadelphia towers," which will be discussed later.

Many high-rise buildings of otherwise fire-safe construction are quite vulnerable to fire spread through utility shafts. This route was how one of the fires in the Empire State Building traveled upward for 67 stories and entered several floors.

These shafts, which are designed to carry pipes and telephone and electric lines, contain enough combustible insulation material for a hot fire, and, surprisingly often, the access doors at each floor are so flimsy that fire can pass through them. Inasmuch as these shafts are not always located in easily accessible places, forcible entry on every story may be required unless master or duplicate keys are available.

Duct Dangers

Ventilating and air-conditioning ducts may convey fire, but more certainly will carry smoke to various parts of a building (Figure 16.4). Because of code requirements that toilets be ventilated, it is often the practice to locate them directly above each other and connect them by a common vertical ventilation duct. This means of smoke travel is why some pictures of hotel fires show heavy smoke pouring out some windows while none is showing at other open windows.

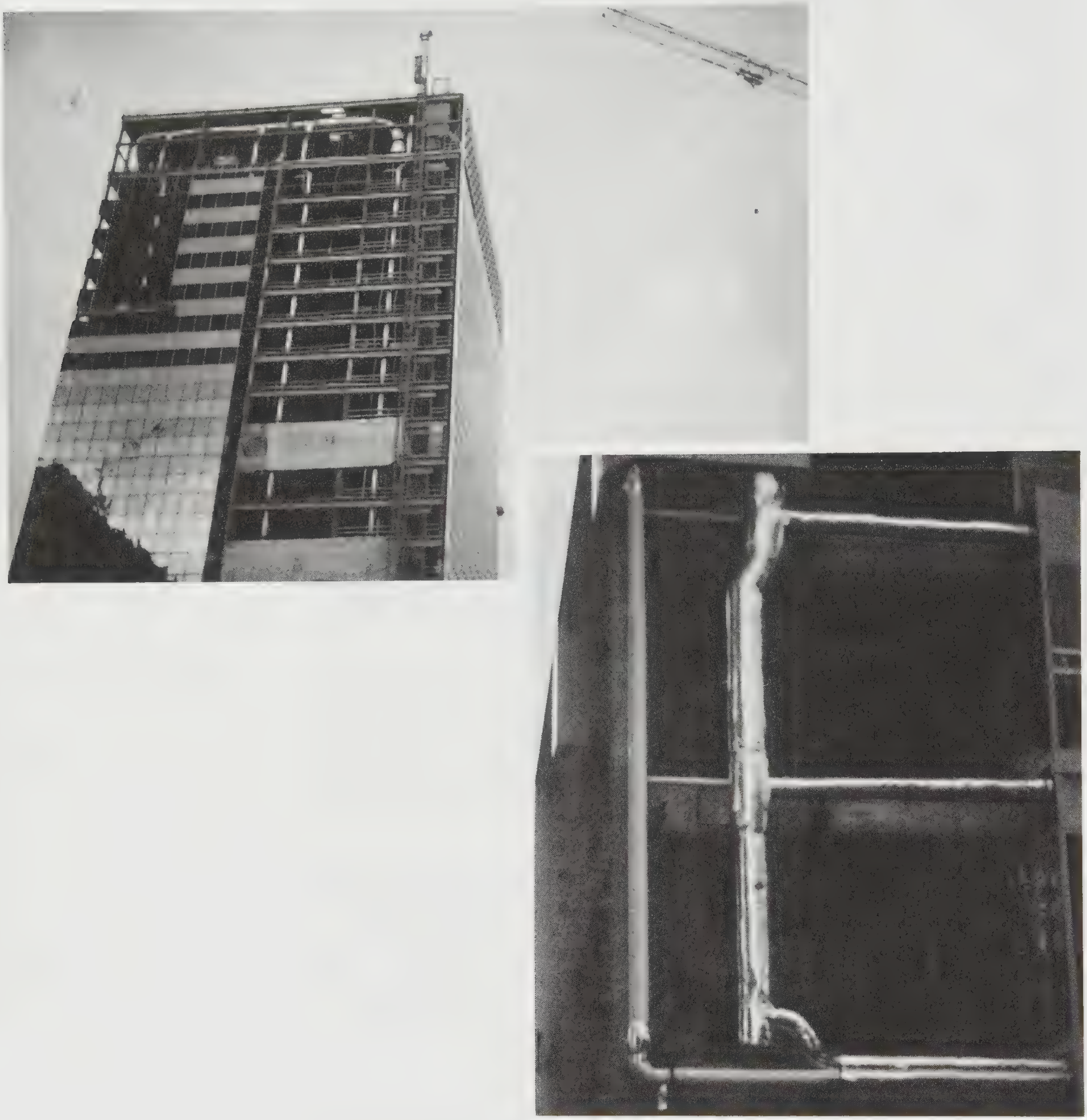


Figure 16.4. A. Modern high-rise structures present more fire problems than the old ones. One of these is central air handling. Here is a last look at ducts which will soon be hidden by walls but will always be ready to convey heat and smoke throughout the building when the occasion arises.

B. A close look shows that central HVAC systems present more than one hazard. There must be an open space between the floor end and the wall for the duct to pass through; often, this means that there will be an opening several inches wide along that wall on every story, thus providing a species of long, narrow chimney for the travel of fire as well as smoke.

The danger of fire communicating through ducts is largely dependent upon wood or other combustible material in contact with or very close to ducts. Although any duct can convey heat, actual fire is found only in ducts with combustible interior insulation or in ducts for some industrial processes and grease ducts from kitchens. The latter are not really grease ducts; they are meant to carry off cooking fumes, but these fumes contain oil and fat, which form a greasy and combustible lining inside the ducts. This greasy deposit can burn with sufficient intensity to allow the metal to reach a glowing orange color and conduct or radiate heat to adjacent material.

Central Core Construction

Of particular interest to today's firefighter is the central core construction used in the more recently erected high-rise buildings. Older high-rise buildings almost invariably had exits on every floor that were remote from each other, usually one on each corner of a building. Such exits serviced a fire stair that led to the street, no matter how high the building. Elevators were built in corridors that did not directly connect with these exits.

In the new central core design, all the elevators, stairs, and, of course, the exits are contiguous to each other in a core that runs vertically through the center of the building. Hallways service each side of the core. In one building we know of, there are five stairways and one elevator shaft all in a row and all opening on the same two hallways. Elevators and stair shafts are, of course, all of Class 1 construction, but, as you can see, the exits are no longer remote from each other. Heat and smoke from a fire can effectively block all exits at once. To complicate matters, the central core building has a highly insulated climate control design in which windows are locked and openable with only a special key. This climate control is a concomitant of a central air-conditioning system which the older high-rise buildings do not have. Part of this air-conditioning system is a common ceiling plenum (hanging ceiling) from which air is returned through shafts that extend through the floors from top to bottom. This plenum is found on each floor and covers greater unstopped areas than had been previously permitted. The plenum also carries utilities.

A further complication of the central core design is provided by exterior wall construction. Now we find thin metal or thin sheets of concrete which, if not properly installed, can permit fire to extend from one floor to another. In addition, steel structural members are frequently spray fireproofed—a coating that can easily be knocked off during construction. Once exposed, such steel members are subject to heat failure, as happened at the spectacular and tragic One New York Plaza fire in New York City.

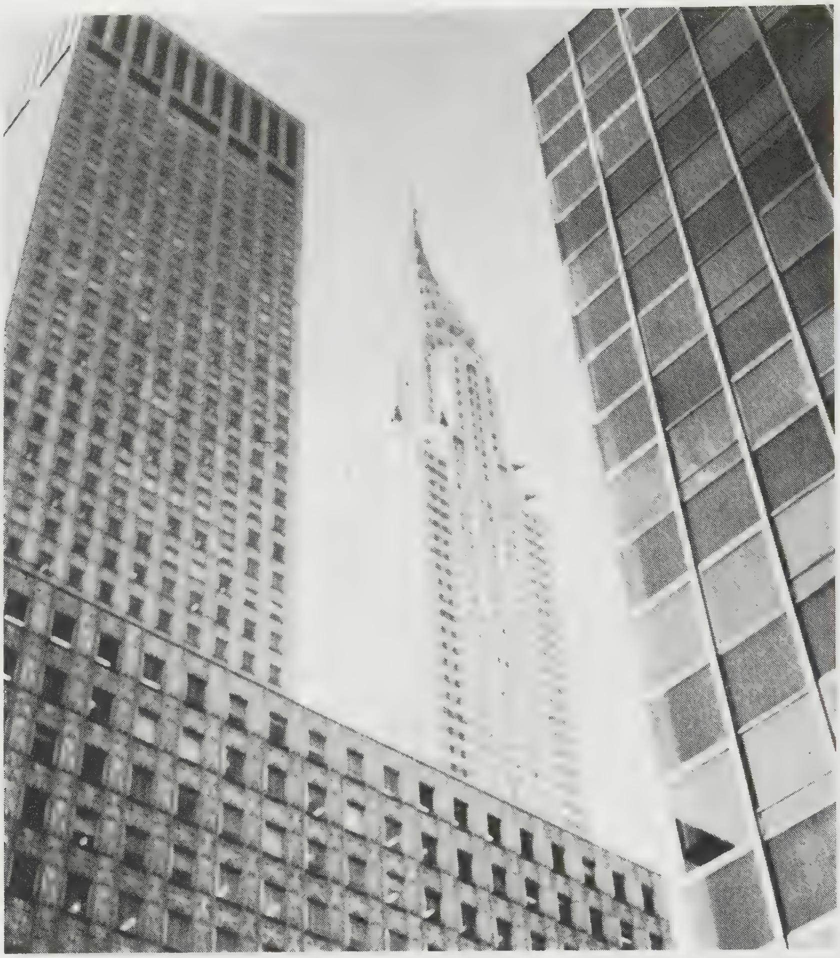


Figure 16.5. *Still one of the highest in the world, New York's Chrysler Building* (center) *was completed in 1931 and represents the type of high-rise construction with brick walls. It is now flanked by two center-core buildings that were erected in the late 1960s. The one on the left has aluminum wall panels; the other, glass.*

Occupancy

With few exceptions, high-rise structures are office buildings, hotels, or apartment houses. None of these occupancies is particularly hazardous or has a heavy fire loading. Large numbers of people occupy these structures, however, and under some circumstances many lives may be in jeopardy. The degree of life hazard depends not so much on the size of the fire as on the building's vulnerability to smoke travel and the means available to escape from smoke.

The contents, although not considered a heavy fire load, still provide sources of fuel for a hot and fast-traveling fire. It should be remembered that a light fire loading means that the fuel sources will be consumed in less time than those of a heavy load. It does not mean that the fire will be less intense.

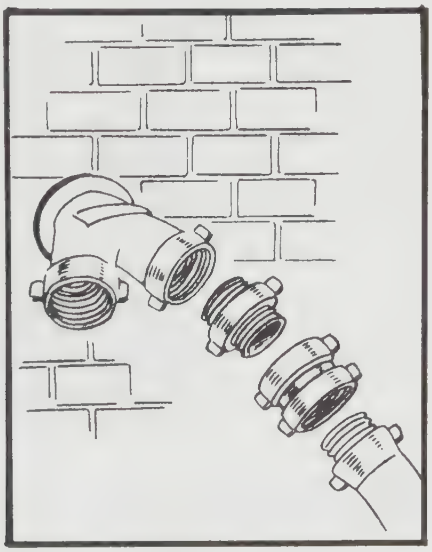
Standpipes

From the firefighting viewpoint, the most important feature of a high-rise building is the standpipe. The structural features lead to the inevitable conclusion that only standpipes make any serious firefighting possible in high buildings (Figure 16.6).

Because of standpipes, less physical effort is required to get water to a nozzle on the eighty-seventh floor of a skyscraper than on the fourth floor of a tenement. In the latter, hose must be stretched by hand up three flights of stairs. In a tall building, firefighters carry three lengths of hose into an elevator, ride to the floor below the fire, hook the hose to a standpipe, and stretch the hose up one flight to the fire floor.

Not only do standpipes save work and time, but they make for a great saving in the amount of hose needed. Another big saving is in the pressure lost through friction. Usually a standpipe has a much larger diameter than hose, thus greatly reducing friction loss.

Figure 16.6. When the swivel on a standpipe siamese won't turn, use double male and double female fittings to connect the supply line from a pumper.



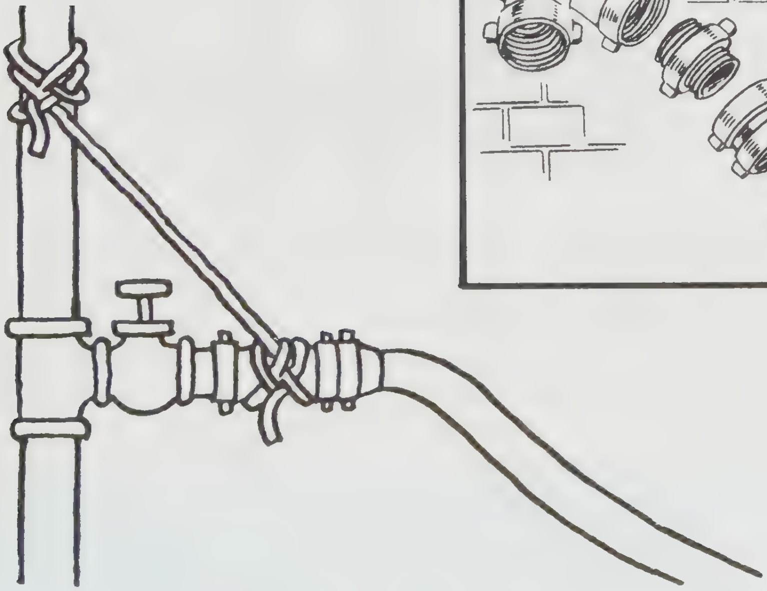


Figure 16.7. When a supply line has to be connected to a standpipe outlet, a double female coupling is used, with a rope tied to the hose and the standpipe to take some of the weight off the coupling.

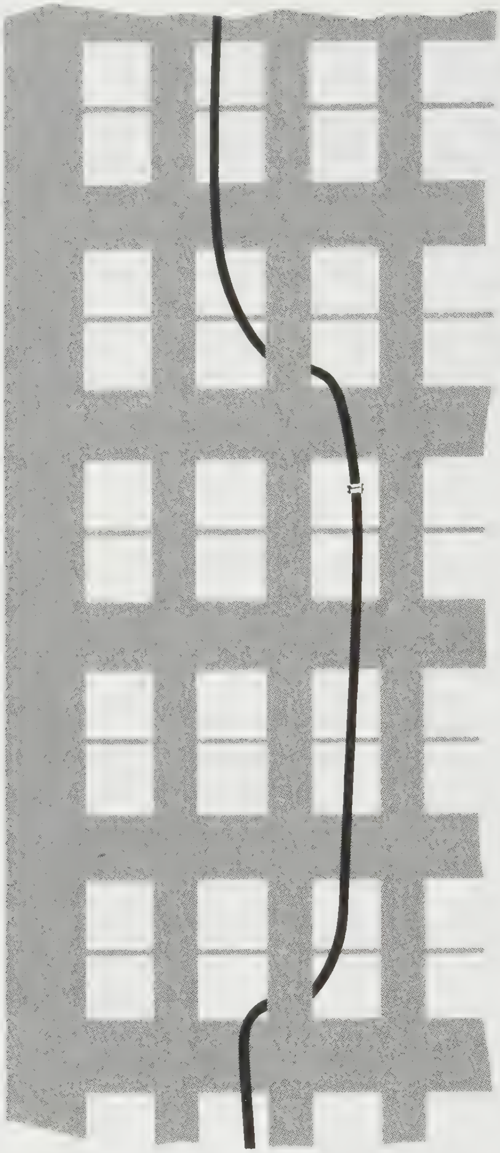


Figure 16.8. Hose may have to be raised up the face of a high-rise when a standpipe is inoperative. The line can be threaded in and out of a window at every fourth floor or so to take weight off the couplings.

A secondary advantage is that standpipes provide a means of quickly getting several hose streams to work on a fire in an adjacent building. From the vantage points of windows in the standpipe-equipped building, these streams not only protect the exposure but sometimes have a telling effect on the fire itself; however, the number of streams that can be effectively taken off one standpipe is limited by the diameter of the standpipe and the capacity of the pump supplying it. The use of multiple hose lines would probably require that at least one—and perhaps more than one—fire department pumper be used to feed a standpipe.

It should be pointed out that the foregoing praise of standpipes is limited to properly designed wet systems. Dry standpipes are of limited value and in some cases are handicaps.

Because of exposure to the weather without adequate maintenance, outside dry standpipe outlet valves can become inoperable and the caps immovable. In some cases, caps are missing and valves are in the open position when water is started. Consequently, water comes out all the open outlets—or everywhere but the nozzle.

Even interior standpipes of modern design have serious drawbacks when they are kept dry. One may rightly wonder why interior systems would be kept dry. The answer is that many colleges are building high-rise dormitories, and the college authorities fear that students will play with fire streams and cause damage if the standpipes are kept wet. Therefore, many college dormitories are being built with dry standpipes, despite the fact that wet systems are accessible to patients in most insane asylums, but are not regarded as a problem there.

One of the deficiencies of a dry standpipe system was shown when the Madison, Wisconsin, Fire Department tested a new system in a university dormitory. This system had four cross-connected six-inch risers. It took five minutes for the air to be expelled from the piping and water to reach the nozzle of a hose line attached to a tenth-floor outlet. The water was being supplied by a fire department pumper at 80 psi through 100 feet of 2½-inch hose, and the hose attached to the outlet was 100 feet of 2½-inch hose with a 1⅛-inch tip.

Another deficiency showed later in the same tests when it was discovered that this procedure had acted to compress air in the other risers. There was evidence that this air was trapped from the tenth (topmost) floor down to the sixth. When the tenth-floor outlet of one of the other risers was opened, air was released with a deafening roar and the flow continued for two minutes through a 1½-inch opening. Although the air pressure was not determined at that time, one can speculate as to the damage it could have done to hose or personnel.

Pressure Safety Margin

Many building codes require only a small safety margin for the pressure the piping and valves must withstand—so small in some cases as to preclude the use of the higher nozzle pressures desired for fog nozzles, especially when 1½-inch hose is used. This situation is the case when a code requires piping to withstand a working pressure 100 psi above static pressure, a commonly found requirement.

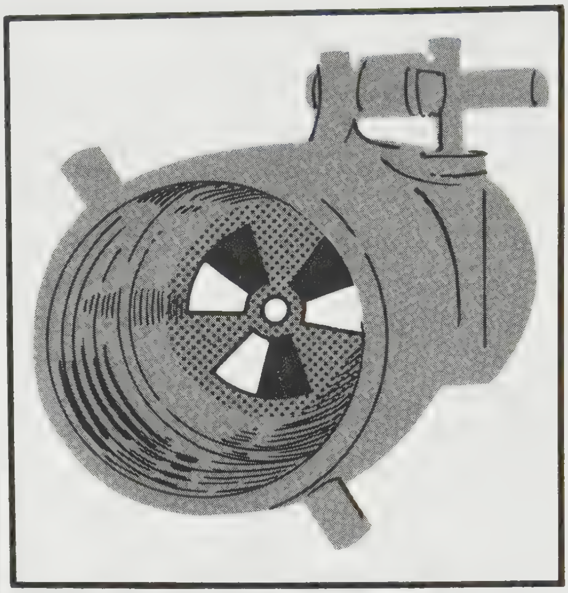


Figure 16.9. *A pressure-reducing valve is used on some standpipe outlets to reduce head pressure in tall buildings. Such a valve permits easy handling of hose line that is connected to it.*

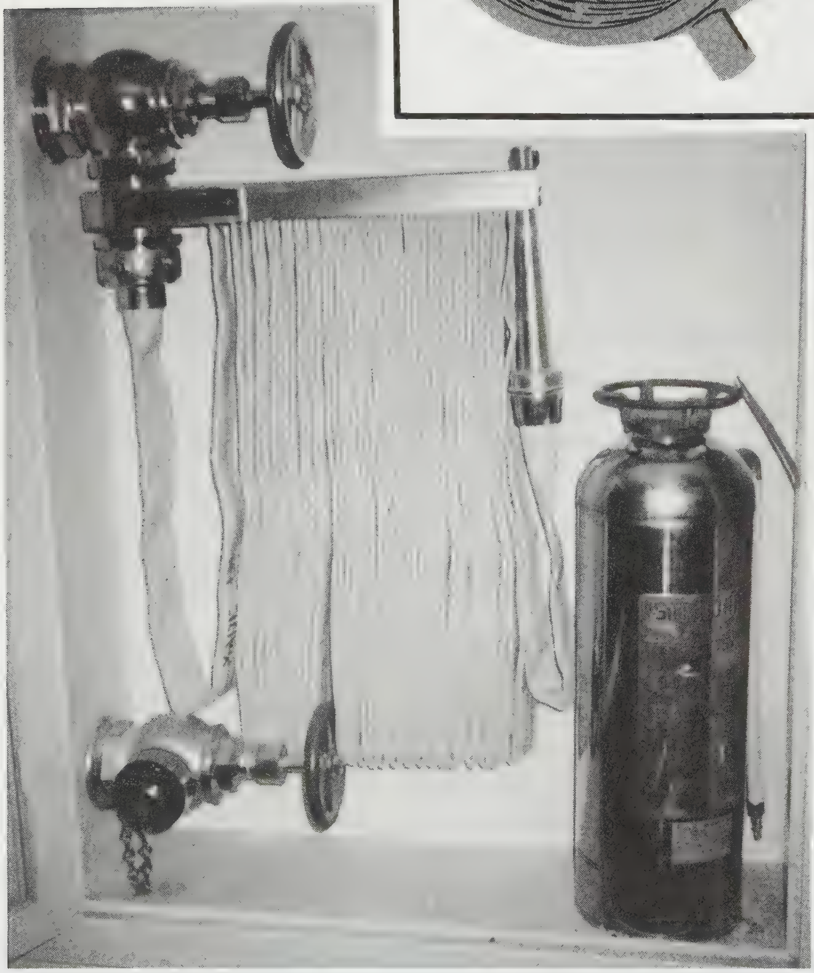


Figure 16.10. *This hose cabinet shows an almost ideal arrangement for a standpipe system. There is a 2½-inch outlet for fire department use, a 1½-inch outlet for the building line, and an extinguisher. It should be stressed, however, that the building hose is meant for first-aid firefighting, not fire department use, and the fire department should bring up enough hose to reach the fire from the outlet selected.*

Another condition that makes the use of fog risky is the fact that standpipes are rarely used and sediment collects in them. It can clog a fog nozzle quickly, perhaps at a crucial time.

The need for caps on standpipe siamese connections was illustrated by a stoppage that happened during a fire in the New York Paramount Building in Times Square. Shortly after a pumper started augmenting the system through a siamese connection, water flow ceased in a hose line connected to an outlet on the twentieth floor. A wallet was later found lodged tightly against the valve on the twentieth floor. Evidently a pickpocket had pushed the wallet into the siamese and past the clapper valve, where it remained until the pressure from the pumper drove it up to the open outlet. The immediate remedy at the time of the fire was to check the outlet on the floor below and connect the hose line to it when it was found operative (Figure 16.10).

When a water flow stoppage occurs during a standpipe operation, the search for the cause should work systematically back from the nozzle. Causes could be: clogged nozzle, clogged outlet, closed valve, empty gravity tank, defective pressure tank, inoperative fire pump, or burst piping. In a dry system, it could be open outlets.

All but the burst pipe can be remedied in a few minutes, and even that can be overcome in some systems. When an airplane crashed into the Empire State Building in 1945, the standpipe was sheared in two, but because the New York City building code required shut-off valves at 150-foot intervals in the riser, firefighters were able to bypass the break with three-inch hose from an outlet below the lower point of shut-off to one above the upper shut-off. The corrective

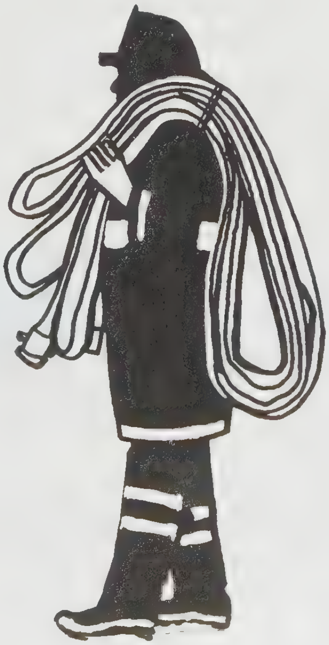


Figure 16.11. *Firefighters can carry lengths of folded hose, as shown, to an upper floor of a high-rise via the elevator or stairs and connect to a standpipe below the fire floor.*

measures for the clogged nozzle, clogged outlet, or closed valve are obvious.

If the system is completely unusable, the alternative is to stretch hose all the way to the fire. Sometimes this task is accomplished by lowering a rope from the floor below the fire and hoisting the hose up the face of the building. When this is done, remember that the weight of one 50-foot length of 2½-inch hose filled with water can be as much as 175 pounds. Therefore precautions should be taken to relieve the strain on couplings, which can be done by securing hose with straps at alternate floors or by taking the line in a window and out another at every fourth floor or so. When either of these methods is used, sufficient hose to advance should be pulled up before the line is charged. Advance will be difficult afterward if the charged line has to be untied and pulled up the face of the building.

Use of Pumper

The loss of supply from a gravity tank, pressure tank, or building fire pump can be overcome by a fire department pumper which should always be connected to the system to provide water in adequate volume and pressure. Usually the pumper is connected by 2½- or 3-inch hose lines to the siamese.

Defective siamese inlets are sometimes encountered, however. One Wisconsin fire department that tested all the siamese connections in town found that many of them could not be used because they had non-standard threads or other defects. If the defect is merely a swivel that won't turn, a double male can be connected to the siamese and a double female then attached to the double male. If the siamese inlet defect is more serious, then the hose can be taken into the building and connected to the nearest outlet by using a double female coupling. The hose line should be charged before the standpipe valve is opened. If the outlet has a pressure-reducing valve, remove it before connecting the hose. Such a method of supplying a standpipe system is quite effective.

Pressure reducers are usually required when the height of a building causes a static pressure of over 50 psi on lower floors (50 psi for 2½-inch outlets and 85 psi for 1½-inch outlets). Pressure reducers are put on the outlets so that if building employees use a standpipe hose line, they won't have difficulty with nozzle reaction due to excessive pressure. Such devices are not needed by experienced firefighters, who prefer to remove pressure reducers and control the pressure with the outlet valve. In most cases, the pressure reducer is set for a smaller nozzle size than firefighters use and will not give the volume or pressure they desire.

Use of House Lines

When there is no building hose on the outlet, a pressure reducer is unnecessary, which brings up the question of whether or not it is desirable to have hose lines, usually called house lines, on standpipe outlets. Some cities require such hose and others prohibit it. The arguments in favor of it are that it enables building employees to fight a fire before the fire department arrives and that it can also be used by firefighters. In opposition, it can be asserted that standpipe hose encourages amateur firefighting by building personnel with a consequent delay in calling the fire department.

As for its use by firefighters, fire departments that have had much experience with standpipe hose won't depend on it and prefer to replace it with their own hose. They feel that the extra time and effort is worthwhile because of the known strength and reliability of fire department hose as opposed to the dubious condition of a house line.

I have seen several examples of the advantages and disadvantages of house lines. There were several instances of delayed alarms—one with a loss of life. Although in some cases the fire was extinguished by the time firefighters arrived, there usually was excessive water damage (which later was probably blamed on the firefighters). Sometimes employees abandoned a house line because of the early leakage, which occurs because of the porosity of unlined linen hose until the fibers swell; they thought the hose was rotten. In other cases, the stream couldn't hit the fire, but that did not deter the amateurs from discharging several tons of water until the fire department arrived. In one hotel, employees poured an estimated 4,000 gallons of water into a two-room suite and still didn't extinguish the fire.

On the other hand, there were cases where prompt action with a house line stopped a potentially serious fire, but in most such instances the individuals responsible had been trained. Some were off-duty or retired firefighters.

At a few fires, the house lines were of help to firefighters. Mostly, this situation occurred where the fire was traveling rapidly through a shaft or duct and lines were needed quickly on several floors. In one incident, four men, working in two pairs, operated lines on four floors as a fire roared through a large grease duct in a 22-story hotel. By using a house line, then shutting it down, leaving it, and repeating the process on another floor, they were able to hit the fire wherever the duct had a horizontal run.

In some localities, a compromise prevails. There are two standpipe outlets on each floor, one of which is 1½-inch with a first-aid house line attached. The other outlet is 2½-inch with no hose attached and is for use only by firefighters with fire department hose.

Where house lines are required, it is often stipulated that the nozzles have straight tips with no shut-offs. This requirement eliminates the possibility of a shut-off being frozen shut by corrosion. Also, inexperienced personnel will not to be baffled by a closed shut-off.

In general, it is better for the fire department to use a standpipe than to drag hose up many flights of stairs, and for the fire department to use its own hose rather than house lines. This method necessitates carrying hose from the apparatus into the building to an elevator to go to upper floors.

Although this hose could be pulled out of the hose bed, it is more efficient to have some hose rolled or folded on the apparatus, ready for standpipe use. Companies that do much standpipe work prefer folded to rolled hose and like folds about six feet long, tied with small-diameter rope near each end. Such a length can easily be carried on a firefighter's shoulder and, when properly tied, can be stood on end in an elevator.

Even if the code requires all portions of a building to be within reach of a 30-foot stream from 100 feet of 2½-inch hose off a standpipe, this length is a straight-line measurement. Much hose may be needed to get around partitions or other obstructions. Usually it is best to bring three 50-foot lengths with a nozzle.

Preference for 2½-Inch Hose

When one is working from a standpipe, it is often advantageous to use 2½-inch rather than 1½-inch hose. The extra weight is not a big factor because only three lengths are involved, and they do not have to be pulled far. The initial standpipe pressure might not be high enough to overcome friction in 1½-inch hose before pumpers get into operation. The smaller hose is prone to kink at low pressures and may not be able to deliver the needed volume. A nozzle with a 1¼-inch tip on 2½-inch hose is usually safe and sufficient.

Although it is widely known that it is dangerous to take an elevator directly to a fire floor, firefighters have been killed or injured because they did just that. The safest way is to get off the elevator one floor, or even two, below the fire and walk up the stairs to the fire floor. This technique also lets firefighters work in a clear atmosphere while seeking a standpipe outlet and connecting hose to it. It may also give an officer an opportunity to get a quick view of the layout on the floor below the fire and relate it to the fire floor. If the building is extensive enough to require more than one riser, the hose must be connected to the proper riser or it may not reach the fire.

When the three hose lengths and nozzle are coupled, there will be considerable surplus hose on the stairway, pending entry to the fire

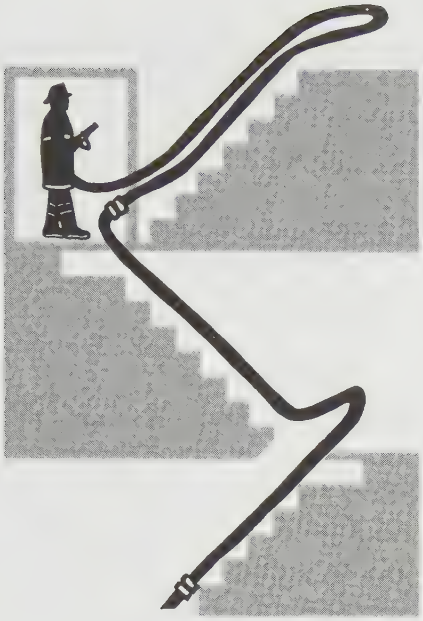


Figure 16.12. *Reserve hose can be stretched to the floor above the fire to allow for sufficient stretch in on the fire floor. It is also easier to pull hose down, rather than up, a stairway.*

floor. While still dry, much of this hose can be pulled up the stairs above the fire floor, making advance easier when the line is charged because it can then be pulled down instead of up (Figure 16.12). Of course, if heat and smoke are not severe, the line can be advanced on the fire floor before it is charged.

Two Supply Lines

To guarantee adequate pressure and volume, a fire department pumper should be connected to the standpipe siamese. It is well to use two lines to assure continuous supply in case one line bursts and also to supply the needed volume if additional hose lines are taken off the system.

The pump operator should know which story the fire is on so he may provide the proper pressure. He should allow 5 psi per story for elevation loss and make suitable allowances for friction loss in the hose and standpipe. The standpipe friction loss is usually almost negligible; an allowance of 10 psi is more than adequate in most cases. The friction loss in the hose needs more consideration but can be estimated in the usual manner.

Another advantage in standpipe operations that is not present elsewhere is the additional control provided by the outlet valve where the hose is attached. If the pump operator is not sure of the exact pressure needed, he can purposely overestimate, and a firefighter can reduce the pressure by partially closing the outlet valve. On the other hand, if pressure is insufficient, there is nothing firefighters in the building can do except send word back to the pump operator.

A small problem that is perhaps worth mentioning is what to do with the 38 gallons of water remaining in the three lengths of hose, especially if the fire was minor and little or no water was applied. The hose can be drained down the stairwell before the lengths are separated and rolled. This amount of water usually can be disposed of without damage at the foot of the stairs, but it could be quite damaging to the fire floor.

Horizontal Ventilation

A suitable assortment of forcible-entry tools and breathing apparatus should be taken to the floor below the fire. The extent of the fire is difficult to determine from the street, and fires in fire-resistive buildings can be extremely punishing because the tightness of the structure holds in much of the heat and smoke. Ventilation can be sorely needed but difficult to accomplish.

Much dependence must be placed on horizontal ventilation, and often doors have to be forced to get the needed cross-ventilation. Sometimes heat and smoke will be so intense that ventilation must be accomplished by breaking windows on the fire floor from the floor above. Usually, conditions on the floor above the fire will be quite comfortable, but if much smoke is present there, it probably indicates the presence of a duct which may carry smoke to several sections of the building.

Vertical ventilation is not ruled out. It may be difficult or hazardous to accomplish in some cases, but it can be quite effective. Even though much of the heat traveling up a stairway or elevator shaft is absorbed by the walls, thus slowing the upward movement of the smoke, there will still be sufficient buoyancy to force smoke and heat through an opening at the top of the shaft if there was much heat to begin with. The limit on vertical travel of heat and smoke in an unobstructed shaft is determined by the amount of heat generated in proportion to the height and area of the shaft. There is also the probability of "chimney effect," which causes the ascent of air or gases in a shaft when they are warmer than the outside air. Experience has shown much heat and buoyancy many floors above a fire. The upward limit for an intense fire is probably greater than the height of any existing structure.

The safety of the firefighters assigned to perform roof ventilation should not be overlooked. In buildings of moderate height, they can walk up the stairs if the door to the fire floor is kept closed until they reach the roof; then they may have to stay on the roof until the stairway becomes reasonably clear of smoke. Of course, smoke should not be vented into a stairway when occupants are using it to escape.

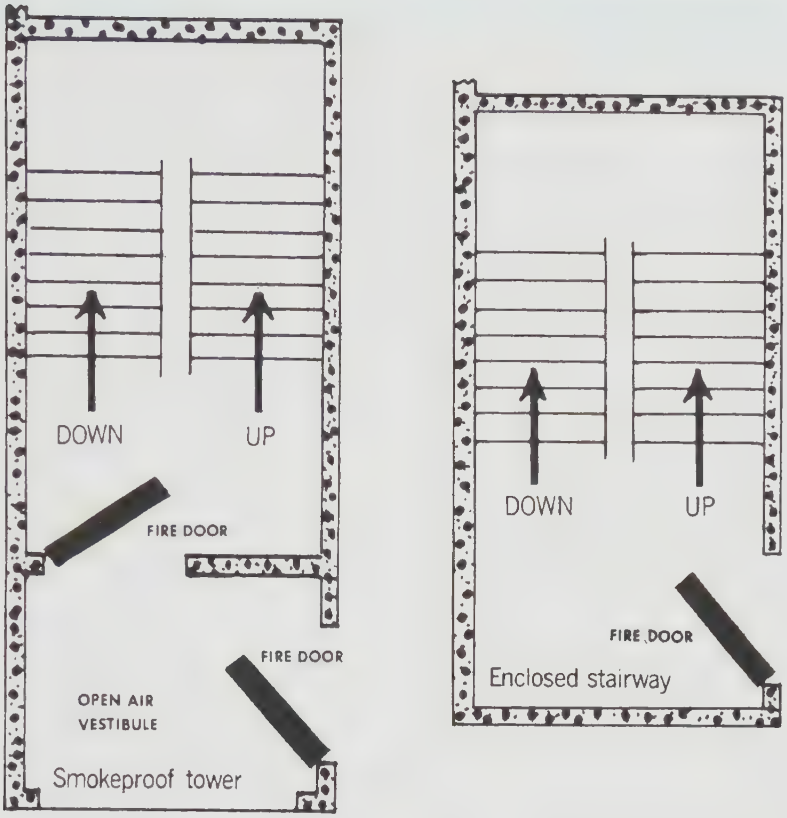

DOWN
UP
FIRE DOOR
FIRE DOOR
OPEN AIR VESTIBULE
Smokeproof tower
DOWN
UP
FIRE DOOR
Enclosed stairway

Figure 16.13. A. *Smokeproof tower includes a vestibule, open to the outer air, that provides a refuge for occupants and access to another part of the fire building.* ***B.*** *A fire door that leads to an enclosed stairway or tower is the most commonly used exit in old and new high-rise buildings.*

Figure 16.14. *This photograph illustrates the severe smoke condition that can occur in a stairway. It is bad enough on the outside stair shown here, but in an enclosed stairway it could cause fatalities, not only on the stairway but also on the upper floors. All this smoke is being generated by a relatively small fuel load: the contents of a single apartment.*

Exit facilities in many high-rise buildings will not guarantee safe egress for all tenants (Figure 16.14). This condition is especially true in apartments where a fire in a room near the door can isolate the rest of the apartment. Consequently, there may be persons calling for help from windows beyond the reach of the longest ladders. Rescue in such cases is usually limited to five choices:

1. Interior rescue by extinguishing the fire quickly
2. Horizontal rescue by firefighters going through an adjoining apartment and conveying victims from one window to another
3. Horizontal rescue by breaching a wall or partition between apartments
4. Exterior rescue by a rope lowered from the roof or a window above the victim
5. Exterior rescue by using a scaling ladder, usually done by first carrying the scaling ladder up an aerial and scaling up the building from the top of the aerial

All of these methods have been tested by experience, but there are others which have been used on rare occasions or which can be imagined, such as raising an extension ladder from the top of an aerial or elevating platform. The life net is not ruled out entirely, but the risk increases with the height. A person jumping from the tenth floor will strike the net with about three times the force of a person of the same weight jumping from the third floor. There have been cases of people surviving jumps of 80 feet, but the maximum safe distance is still a matter of conjecture. Stunt men have jumped on to air-filled escape bags from greater heights.

Elevators

In some cases, elevators may be jammed by fleeing occupants, or firefighters may find them difficult to obtain quickly because of normally heavy traffic. The latter is often true of self-service elevators. It is best for firefighters to take command of one elevator for their exclusive use. Sometimes a key for this purpose can be obtained either at the fire or in advance (Figure 16.15). The use of this key allows the overriding of normal automatic responses to eliminate stops on intermediate floors. When it is not obtainable, at least some control can be had by leaving a firefighter in the car to operate it and keep it where it is desired by holding the doors open.

There is controversy over the use of elevators by firefighters. Some departments—especially where there have been elevator fatalities—prohibit their use. What is the practical solution? Perhaps firefighters with the weight of SCBA, hose, and tools could endure a climb of ten

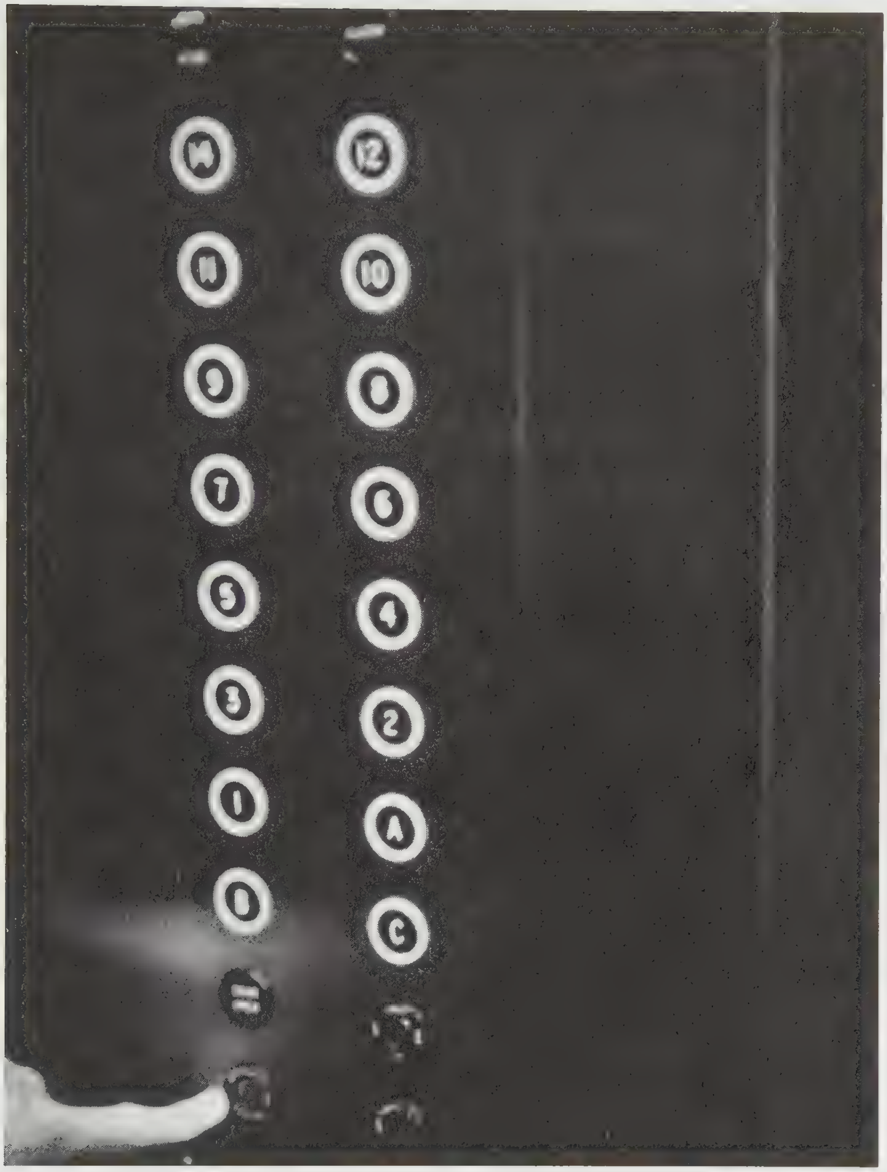


Figure 16.15. The slot for the fire service control key is usually found at the top or bottom of the elevator control panel in each car or in designated cars. If fire companies don't carry the key, they should know how to obtain it quickly.

stories, but how much more? An article in *Fire Engineering* describes a drill in North Carolina:

> ". . . this company proceeded with S.C.B.A. and a high-rise kit to the 16th floor via stair tower. Twenty minutes later an exhausted crew arrived at the fire floor."[1]

Deputy Chief Elmer Chapman (retired), who spent many years in the world's greatest concentration of high-rise buildings in midtown

Manhattan, defends New York's policy of using elevators as follows:

> "The use of elevators to respond to high-rise fires in New York City is looked upon as an extension of the fire apparatus in the transportation of firefighters to the location of a fire. We do not walk to fires because there is a possibility of an apparatus accident en route. We observe all safety procedures to ensure our safe arrival. The same can also be applied to the use of elevators. Safety procedures must be known and observed to ensure the safe use of elevators to transport the firefighters to the location of a fire.
>
> There are companies in midtown New York that may respond to as many as ten alarms a day in high-rise buildings. It would not be reasonable to expect these companies to walk up to each of these alarms. They must be trained in and observe all the safety procedures that have been outlined for operating at high-rise building fires. The major problem that this frequency rate causes in the use of elevators in high-rise buildings is complacency."[2]

The New York City fire department's instructions require that no more than six members ride in one elevator, and they must carry forcible-entry tools. They are also told to push up the ceiling hatch cover or open the hinged side panel and direct a flashlight upward. This light may reveal smoke in the shaft and warn against the use of this particular elevator bank. The lobby command post should record what elevators are being used, by what units, and to what destinations.

Service elevators may be safer because they usually serve all floors and can be operated on manual. Before entering elevators, firefighters should note the direction of the stairway and the distance to it.

Another precaution is to try the controls shortly after leaving the ground floor and, if they don't work, to stop the car by means of the emergency button or by forcing the door open if the emergency button fails.

Elevator cars, doors, and shafts may be incombustible, but they are not fireproof. Smoke from a fire in an occupancy may quickly enter an elevator shaft and travel upward, creating a hazard not only within the shaft but also on the upper stories of the building. Smoke travel downward from the fire floor is not as likely but can happen where fire starts above the neutral plane. This downward travel of smoke is usually not hazardous, but it can be deceiving when the location of the fire is being sought.

The danger of fire entering the shaft is not great. There is little to burn in the shaft itself other than grease on the cables and equipment, but there may be a considerable amount of grease. Sometimes at the bottom of a shaft there is an accumulation of grease and rubbish, which can provide sufficient fuel for a fire. The car doors and the shaft door will not usually be seriously affected by such a small fire, but they can be distorted by the heat of a sizeable fire in an occupancy on one of the stories.

In manually operated elevators, the life hazard to firefighters and building occupants using elevators during fires is minimal. With elevators that are programmed and automatically controlled, there is considerable risk of the cars going to the fire floor, accidentally, and staying there.

There is a type of electronic call button that is not activated by the pressure of the finger but by a difference in capacitance. This type of call button can be activated by the heat of a fire or by smoke, thus calling the elevator car to the fire floor; this effect was confirmed at tests of high-rise fire, at 30 Church Street, New York City. Even mechanical call buttons can be activated by temperatures above 450°F.

Most automatic elevators have an "electric eye" device to hold open the doors as long as the light beam across the doorway is interrupted, so that a person leaving or entering the car won't be struck by a closing door. Yet smoke of sufficient density to interrupt the light beam will also keep the doors open. People, including firefighters, have been killed because of this mischance. A manual override of this feature is available, but perhaps more desirable is an automatic time control which will try to close the door at a specified time (usually 30 seconds) after it has opened, regardless of obstruction.

Heat and smoke may rise in the shaft to the machine room and nullify the control mechanism. Heat could cause failure of hoist cables and tripping of circuit breakers. Water may also disable elevators by tripping circuit breakers or causing fuses to blow.

The "National Elevator Code" (ANSI-A17.1) of 1973 requires several safety features which could be valuable if fire were to occur. Among these are a device to assure that doors will not be held open by smoke; a key switch in the main lobby to return all cars to the main floor, non-stop; and a smoke or heat detector above the call buttons on each story to do the same. The emergency call to the main floor would not only void all call buttons, but would reverse upward traveling cars and prevent the emergency stop button in each car from being effective if pushed. Of course, these code features are not retroactive and not universally required; therefore they will not always be present.

One of the first actions to be taken by firefighters arriving at a fire in a high-rise building is to check on the whereabouts of every elevator and try to determine the condition of each, because occupants may be trapped in cars on or above the first floor. The firefighters should then decide whether or not to use the elevators. The aforementioned 1973 code requires that each car with a rise above 70 feet be equipped with a special key switch which would enable a firefighter to operate the car independently and manually. It would then stop only at the floor which he desired and the door would open there only when he pushed the door-opening button. If he took his finger off the button before the door was fully open, the door would close. It should be remembered, however, that power failure and some of the other causes previously listed may cause the car to stall between floors. This stopping happened in New York City in a blind shaft, but fortunately the firefighters trapped in the car were well equipped with forcible-entry tools and were able to open the car doors and breach the shaft wall. Thus it appears that suitable tools should be carried by firefighters as a precaution against such an occurrence.

Some of the existing elevators can also be taken off automatic control by a key switch. Usually one of the cars in a shaft is so equipped for use by building personnel who have the key. Firefighters could borrow the key or perhaps find it in a previously learned location.

In addition to using their own radios, firefighters may be able to utilize the telephones found in many elevators. Use of these phones, like the location of keys and switches, should preferably be learned in advance through pre-fire planning. Such planning should also include the types of emergency exits on the cars, how to open them, and how expert elevator mechanics can be called. Pre-fire inspections should note if any switch keys or door-opening tools are missing from their proper receptacles, and steps should be taken to have these deficiencies rectified. It should be determined whether or not escape hatches are readily openable. Many have been bolted shut to prevent "joy riding" atop the cars.

Equipment

There is rarely need for taking up more than the usual forcible-entry tools, hose, and nozzles. Some departments with very little high-rise experience carry such a wide variety of miscellaneous tools that they could make permanent repairs to the building.

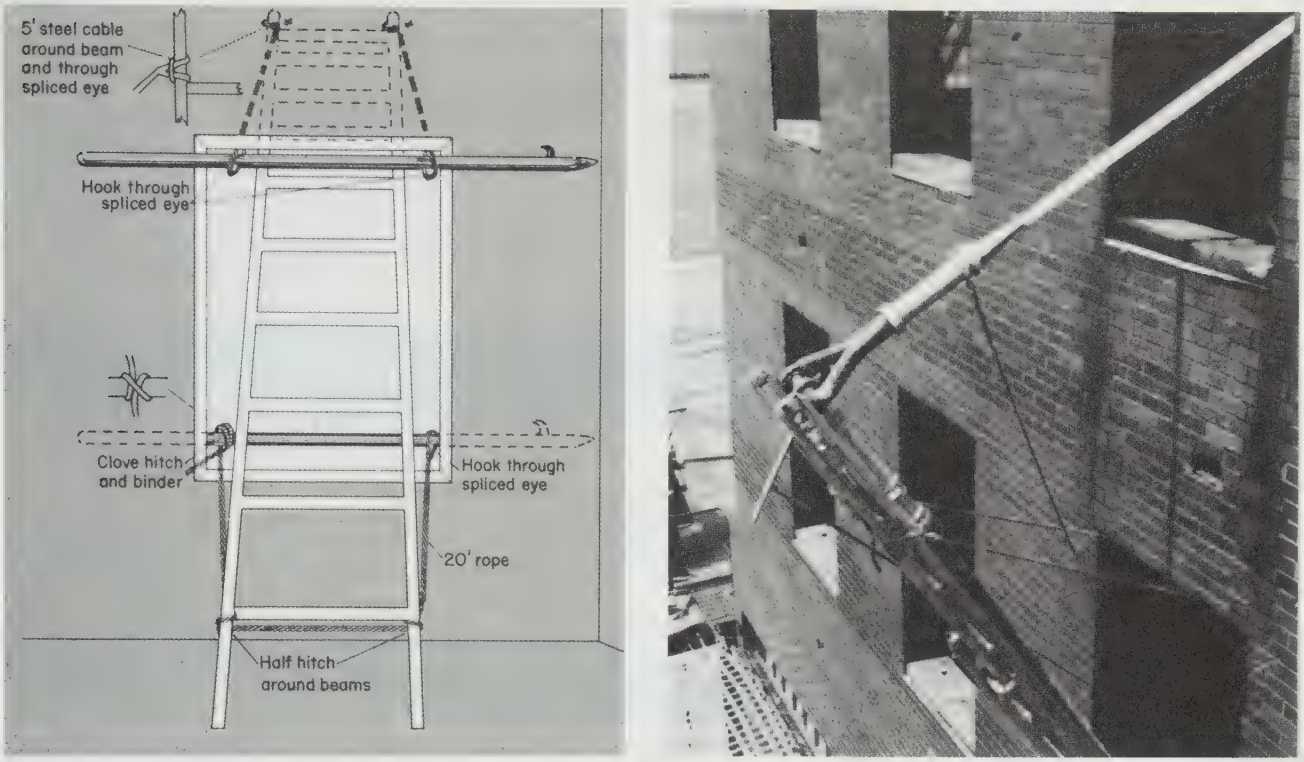

5' steel cable around beam and through spliced eye
Hook through spliced eye
Clove hitch and binder
Hook through spliced eye
20' rope
Half hitch around beams

Figure 16.16. *A novel idea to provide an outside approach for high-rise rescue and firefighting is offered by Lieutenant Peter Lorenzo of New York City. Other than an extension ladder and a ladder pipe, it requires two pike poles (hooks) and some rope and cable. Experimentation might develop variations for local conditions.*

Stairs

Some stairs are of the return type, which has the doorways in the same position on each floor. Some may be scissor stairs, with doorways on the opposite side on alternate floors. (If the door on the even-numbered floor faces north, that on the odd-numbered floor faces south.)

Firefighters may encounter difficulty going upstairs against a number of occupants trying to get down. It isn't necessary for these occupants to get all the way down, but just far enough below the fire to be safe. Then firefighters should direct them off the stairs and on to the proper floor.

Command and Control

There should be a lower command post established in the lobby, an upper command post two floors below the fire (if practicable), and a staging area on the floor below that. Radio communication may be difficult in some buildings. New York has used a 36-inch antenna with a magnetic base and has tried cross-band repeaters to connect the upper and lower command posts through a chief's car in the street. Chief Chapman suggests that cellular phones show the most promise. (New York City also requires telephones in elevators connected to the control panel in the lobby.)

HVAC

At some high-rise fires, the system for heating, ventilating, and air conditioning (HVAC) can be beneficial or harmful, depending upon the type of system and the operational mode. Some buildings, especially apartments, have independent units for each apartment. If these draw their air from an inside corridor, they will pull smoke from the corridor into the apartment. At some fires, those who had the air conditioner on died, while on the same floor others who had it off survived.

In office buildings and larger high-rise structures, central systems prevail. Normal operation can be a problem. It will provide more air to the fire and recirculate the smoke. The other options are total shutdown; shut down supply and operate exhaust; shut down exhaust and operate supply. In some buildings, it may be possible to effect separate operations on different floors.

Ventilation

In buildings such as apartment houses not over 15 stories or so in height, the conventional ventilation methods can usually be employed safely and effectively. In office buildings and taller structures, the problem is not so simple. Window glass may be ¼-inch to ½-inch thick and, when broken, may fall as dangerous shards some distance from the building; the area below should be kept clear.

In all high-rise buildings, there is a "stack effect" and neutral pressure plane. If the air in the building is warmer than the air outdoors, there will be an upward movement of air in vertical shafts, such as those for elevator, stair, and trash; however, if it is warmer outside than in, the air in those shafts moves downward.

The neutral pressure plane is the level at which the outside pressure and inside pressure are equal. Above it, when a window is open air will move out, but on a floor below the neutral plane, air would move in. The height of the neutral plane varies with the relationship of inside to outside temperatures. At the time of a fire, a test could be made on the floor below, on the assumption that the air movement on the fire floor would be the same.

Some buildings have pressurized stairways to keep smoke out. This system requries permanently installed high-pressure fans to maintain adequate pressure, especially when doors are being opened frequently, or held open, as they may be during a fire, and, of course, top ventilation would reduce the efficiency. In non-pressurized stairways, however, top ventilation may not only be desirable but of critical importance; it can be assisted by positive-pressure ventilation from well-placed fans.

Evacuation

Should the occupants leave or stay? That is a controversial question. Some say, "Get the fire out, not the people." There is much evidence to support this theory—but, in a few cases, large numbers died before the fire was extinguished. Smoke movement is the determining factor. The average person cannot be expected to travel through smoke-filled halls or down stairs obscured by smoke. Moreover, as far as rescue is concerned, the firefighters will probably lack the personnel and equipment needed for total evacuation during the critical period. Dispatchers receiving calls from occupants should give them appropriate instructions, find out just where they are, and notify the incident commander.

Helicopters

The value of helicopters is quite limited. I haven't found a documented case of a life being saved by a helicopter at a fire in the U.S. True, there have been people removed from roofs, but they were perfectly safe where they were. The only case I know of where people endangered by fire were taken from windows occurred in Sweden. Even under ideal conditions, taking many people off a roof is a lengthy and usually unnecessary procedure. It would probably be better to put firefighters or, better yet, policemen on the roof to control the crowd until the fire is out, or to direct evacuation if that does become necessary.

Buildings Under Construction

There have been several fires in high-rise buildings under construction. One of the first and worst occurred during the erection of the Sherry Netherlands Hotel in New York City in 1927 and taught some lessons that are still applicable. Construction on this 38-story building, which towered 559 feet, was advanced to the point where the exterior was almost finished. Although two 8-inch standpipes were in place, they were uncapped. This unpleasant fact became known to the firefighters only after they had started pumping into them. No elevators had been placed in service as yet, and, as the two material hoistways had been rendered inoperative by the fire, the hose had to be carried up the stairs. Since then, many codes require standpipes to be capped as they are extended.

Fire can progress rapidly in a building under construction because it is open to the air and offers few obstructions to fire travel. Another reason is the presence of much combustible material such as scaffolding, forms, supports, packing cases, cartons, and the like. Oxyacetylene welding equipment is usually present. Sometimes there is gasoline stored for hoist and other engines.

Potential ignition sources are careless smoking, welding sparks, plumbers' torches, salamanders, gasoline engines, and temporary electric wiring. Rubbish in the form of discarded cartons and packing paper accumulates at an alarming rate, and, if not removed frequently, it will present an easily ignitable fuel source of considerable volume.

When construction has not advanced much beyond the skeleton stage, certain problems will be encountered and measures must be taken to cope with them. First is the hazard of footing. Construction crews, working in daylight and familir with the environment they have created, will place planks from girder to girder. Firefighters, arriving in total darkness, may have to find their way along this precarious footing. I well remember a night when we had to climb temporary construction ladders for 12 stories and then tread gingerly on unfamiliar planks to reach a fire in a building under construction. At a time like this, illumination is important because a misstep can be fatal. It is also a time for officers to exercise the strictest control over the movement of personnel for their safety.

Another hazard to be considered is that objects dropped or knocked down may strike firefighters beneath. Hose streams may dislodge planking or construction ladders. Boards may burn through and drop, creating a safety hazard and starting other fires below.

Sometimes the most efficient way of attacking a fire in a skeleton structure is with a heavy stream from a ladder or deck pipe. This kind of stream may be able to reach through the open structure for a considerable distance and do effective work well beyond the nozzle.

High-rise fires, more than any other, are best fought on the drawing board. Built-in protection is essential to limit the spread of fire and to provide safe egress for large numbers of people (as many as 25,000 in one New York skyscraper).

There have been several attempts through the years to cope with the problem of providing absolutely safe egress, none of which has proven completely satisfactory. The Philadelphia tower is a modified fire escape that incorporates a staircase reached by walking across a short balcony open to the outdoors. In theory the open passages prevent smoke from getting into the stairwell. The "smokeproof" fire tower is similar except that the intervening vestibule is enclosed rather than open to the outdoors. The chief reasoning behind its design is that self-closing doors at each side of the vestibule will not both be open at the same time.

It is my contention that the quickest, easiest, and safest egress can be had horizontally if provision is made to divide the building vertically into two sections separated by smoke-tight, fire-resistive partitions with self-closing doors. If such walls had but a one-hour rating, there would still be plenty of time for evacuation after horizontal egress had been achieved.

One of the saving features of high-rise buildings is that they seldom contain heavy fuel loads. In occupancies that are heavily loaded, automatic sprinklers should be required.

Standpipe systems should receive paramount attention in planning for fire safety. Risers should be of ample diameter and properly spaced and located in stair enclosures. Siamese connections should be readily accessible and clearly identified; they should be on the street front of the building and not hidden at the rear or side. Whenever a building faces on more than one street, there should be a siamese connection on each street. All risers should be cross-connected so that supplying any siamese will charge the entire system. Each system should have both primary and auxiliary sources capable of maintaining adequate supply and pressure even on the topmost floor. Valves and piping should be designed to withstand the maximum pressure to which they may be subjected, plus a good margin of safety.

It should go without saying that the threads on all outlets and inlets should be the same as the fire department threads, yet this point is often overlooked by builders and architects.

Siamese connections should be marked permanently for easy identification so that those for supplying the standpipe can be distingushed readily from those leading to other systems, such as sprinklers. This identification should be spelled out in raised letters for standpipes and depressed letters for sprinklers so that they can be identified by touch in darkness or smoke. In addition, New York City requires color coding so that a siamese connection can be identified from a distance. The inlet caps must be red for standpipes, green for automatic sprinkler systems, silver (aluminum) for non-automatic sprinklers, and black for ammonia mixers.

Inspection should include a check of the threads on all inlets and outlets to make sure they are compatible with fire department threads.

Firefighters should be well trained in the use of standpipes.

Building superintendents should be indoctrinated with the importance of keeping standpipe equiment in good condition and notifying the fire department when a system is inoperative or being repaired. The use of hydrant out-of-service disks will save valuable time by indicating whether a siamese or an entire system is out of order.

When the high-rise fire problem comes to town, the solution is not the acquisition of longer aerial ladders or special equipment. Rather, it is found by adapting firefighting methods to take advantage of the good features and overcome the bad features of such structures and by incorporating a maximum of desirable facilities in building design.

ELECTRICAL FIRES

The Class C designation for electrical fires applies to energized wires or equipment. When the current is shut off in electrical fires, the fire becomes either Class A or B, depending on whether or not oil is involved. Therefore, the extinguishing methods for a fire involving electricity would be the same as for a Class A or B fire. When the current is on, however, due regard should be given to the shock hazard and arcing.

Small Class C fires can be extinguished safely with carbon dioxide, dry chemical, or halon extinguishers. Water in the form of fog is

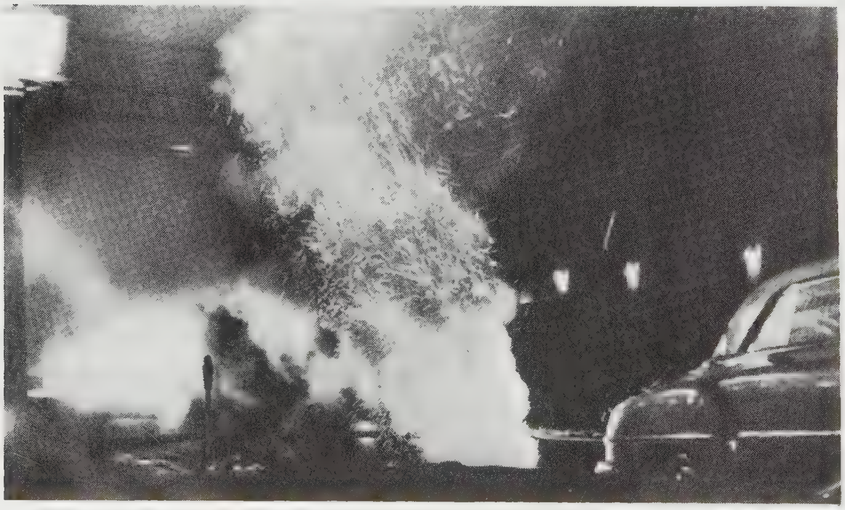


Figure 16.17. A short circuit in an underground cable provided this shower of sparks at a manhole. Usually, in such a situation, firefighters should only protect the surroundings while awaiting the arrival of skilled utility crews.

also safe. Dry chemical and water, however, may create a clean-up and restoration problem for some kinds of electrical equipment, although in many cases the fire has already done enough damage to require rebuilding the equipment.

On larger fires which are beyond the capability of extinguishers, water in fog form is indicated. This method always raises the question of whether water conducts electricity. Pure water is, of course, a nonconductor; it is actually the dissolved minerals in water that make it a conductor. A straight stream of water, therefore, can conduct electricity, but not very well. There is no documented case of a firefighter being killed by electricity conducted through a stream of water, either solid or fog.

It is possible for a person holding a nozzle to get a low-order shock through so-called solid stream or a straight stream from a fog nozzle, but the danger would not be so much that of electrocution as losing control of the nozzle due to reflex action.

Because there are air spaces between the water drops in a fog stream, the electrical conductance is limited, and such a stream is generally regarded as safe to use on energized equipment, even up to fairly high voltages. There are still, however, indirect hazards which should be avoided. For instance, it is not advisable to approach a high-voltage source closer than one's body length, so that a forward fall would not cause direct body contact. Another precaution is to stay out of puddles; current may be traveling along the puddle horizontally on its way to a grounded object. If a person is standing in the puddle with feet apart, the current may travel up one leg and down the other on its way to the ground. It is not necessary that the puddle be there first. It could be formed at one's feet from the water applied to the fire.

There may be cases where a straight stream is accidentally directed on to high voltage. Therefore, it would be well to know what might be expected. I was working at a lumberyard fire when an engine company nearby struck an 11,000-volt overhead wire with a stream from a 1⅛-inch nozzle. The result was thunder and lightning—a bright white flash accompanied by a big noise. It was at night; the light was visible for miles, and the sound was heard over a considerable distance. As for the firemen holding the nozzle, all they suffered was surprise; they did not feel any current and continued operating without harm. The distance from the nozzle to the wire was about 40 feet.

Tests have been conducted by several universities and fire departments to discover safe distance limitations for straight streams on electrical equipment. But results vary somewhat and there are differences of opinion on what is the most amperage an individual holding a nozzle can safely sustain. Another variable is the mineral content of the water, which controls its resistivity. Purdue researchers found a range of 710 to 5,400 ohms per cubic centimeter in public water supplies in Indiana. The lowest values were found in deep well supplies, and the highest in those from lakes and rivers. Tests by the Chicago Fire Department showed that the water from hydrants had much higher resistance than that from the Chicago River. The higher the ~~number of ohms~~ resistance, the less conductive is the water. The safe distance, then, varies considerably with the resistivity of the water. For instance, the Chicago hydrant water would be considered safe (maximum 3 milliamperes conducted) at a distance of nine feet from a 2,200-volt source, but the river water would conduct the same amperage for a distance of almost 23 feet.

Another variable is the diameter of the stream. The larger the diameter, the greater the conductivity. The safe distance is doubled when the nozzle diameter is increased from ¾ to 1¼ inches.

From the various test data available, it appears that, with the exception of a power plant, fires in buildings would rarely present voltages which would be highly hazardous if accidentally struck by a water stream. Even if an outside stream strikes a high-voltage transmission line, the distance from wire to nozzle is usually sufficient to preclude a dangerous level of conductivity.

The danger of electrocution through hose streams is minimal, but several firefighters have been killed by ladder contact with electric wires. In three of the four cases with which I am familiar, the man was in contact with the ground; these cases are discussed in the chapter on safety. Another cause of electrical injury, also mentioned in that chapter, is the cutting of electric wires. Suffice it to say here that wires should be cut only when necessary. Aside from the safety factor, there is the loss of power which could have been valuable. Some rural fire departments routinely cut the wire feeding a farm when they have a fire in a farm building. This action is seldom necessary and in one case actually did harm by cutting off power to a large well pump which could have provided the water needed to extinguish the fire.

There are times when an arc may ignite the oil in a transformer. The transil oil is of high flash point and can be extinguished with fog. If this task can be done from the ground, there is no great danger except that of being struck by a falling wire, but firefighters should not climb the pole to attempt extinguishment at close hand.

When a wood pole is wet, it should be regarded as a conductor. Firefighters should not only steer clear of it but also keep others away.

It is not recommended that firefighters cut live wires except in extreme emergency, and then it should be done only with approved wire cutters (not bolt cutters or other tools) and wearing lineman's gloves which are in good condition. When it is necessary to cut a wire, care should be taken to keep loose ends from lashing around when released.

Underground Fires

Where electrical conduits travel under city streets, vault and manhole fires are common occurrences. They are not all alike. The first one I ever worked at was quickly and easily extinguished by emptying a 15-pound carbon dioxide extinguisher into the manhole, but I haven't seen this method used successfully since. In some cases, an explosion of gases will send a heavy manhole cover hurtling through the air. In one case, an unfortunate citizen was crossing a Brooklyn street, and this explosion occurred as he stepped across the manhole. What happened to him should serve as a warning to firefighters that they should use a careful approach to a smoking manhole with the cover still in place.

In another Brooklyn manhole fire, the explosion took place after the cover had been removed. It badly burned a firefighter who was leaning over the manhole. I have seen cases where several manhole covers blew off on the same street.

When the fire department is called for smoke coming out of a manhole, the first step should be to keep everyone clear; the second, to notify the electric company; and the third, to examine the electric entrance and fuses in all buildings in the block. It is also a good practice to pull the main service switch in these buildings to the off position and remove fuses, but don't count on this action as being

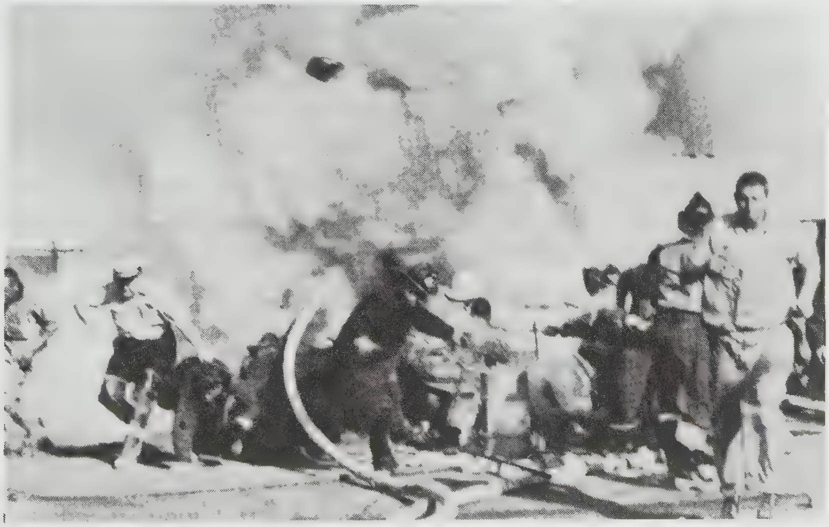


Figure 16.18. *An explosion of pent-up gases in a manhole sent firefighters scrambling for safety, including the one whose helmet is flying in the air* (upper left center).

effective in protecting the building. Current gone wild is a sobering sight. In one case, we arrived on the scene to find smoke pouring out of a manhole. As second-due ladder company, we were sent into several buildings to pull the main service switch. We did so and were dismissed, while the first-due engine, ladder, and battalion chief waited for the electric company's emergency crew to arrive (standard procedure). It was a long block, and we had to back the ladder truck out. Just before we reached the corner, we were called back and ordered into the buildings where we had pulled the switches and removed the fuses. The wild current had jumped both switch and fuse box; the fuse box was melting and BX cable across the cellar ceiling was glowing yellow hot.

Therefore, a fourth step is added: keep checking electric entrances in buildings on the affected street until after the wires have been cut by the electric company, or the situation is guaranteed safe by its responsible employee.

Firefighters should not enter manholes unless to save a human life. Water should not be used in manholes unless at the request of the electric company. If water has been used prior to the arrival of the electric company crew, they should be so advised. The same is true of other extinguishing agents. Water could pool and puddle and thus present a dangerous conductor to the individual working in the manhole after the fire. The presence of carbon dioxide in a manhole may require forced ventilation before the area is safe for an individual without breathing apparatus.

If it is necessary for firefighters to enter a manhole, they should wear self-contained breathing apparatus. Flashlights and other equipment should be explosion-proof.

If fire involves a power plant or other high-voltage installation, certain precautions are advisable. First, the electric company should be notified. The fire should not be attacked directly with water unless absolutely necessary. If water is used, it should be in fog form and from as far away as would be effective. Advice should be sought from those employees of the electric company, or the building involved, who are competent to give such advice. (The authority and competence of these employees should have been determined through prefire planning.) Current should be cut off as soon as is safely possible. There have been cases of current being turned back on by mistake; this possibility should not be forgotten.

In an ordinary building fire, there is seldom need for discontinuing the electric service to the building; at least, there is no justification for doing it routinely. If electric equipment is involved, there is no need to cut off the whole building if the involved area can be handled separately. When current is cut off—even partially—the electric company should be notified. In fact, it is good practice to notify them whenever electricity is involved in a fire.

FLAMMABLE-LIQUID FIRES

When flammable liquids are mentioned, the first to come to mind are the petroleum derivatives, such as gasoline, benzine, naphtha, kerosene, fuel oil, diesel oil, and the various jet fuels. There are, however, other liquids which are quite flammable, but not as frequently encountered.

Gasoline
1' per hour
Burn Rate.

There is a time-worn expression that "oil and water don't mix." It is very true in firefighting, where it applies to liquids which are oils, but there are many other flammable liquids which are miscible with water. When water is mixed with them, their flash point increases as the percentage of water is increased, until the mixture will no longer emit flammable vapors. This effect is so with alcohols and acetone. Extinguishment is arrived at by dilution with water, although for larger quantities other methods may be faster.

Another chemical that can be extinguished with water is carbon disulfide, which is heavier than water and can be covered with it. This method could be called extinguishment by a water blanket.

The petroleum products of higher flash point, especially those which only flash above 100°F, can be extinguished by water spray, which cools them below the flash point. The liquids of lower flash point, which have flash points below ordinary ambient temperatures, cannot be cooled sufficiently by water; therefore other methods must be used.

Hence, the extinguishment problem is determined by the amount of surface involved. Even though the total quantity of liquid is great, if its surface is small, the fire is small. Fires up to 25 square feet in area can be handled quickly with carbon dioxide extinguishers, especially if there is no wind to contend with. Larger fires can be extinguished by dry chemical. Purple K dry chemical portable extinguishers have ratings up to 80:B, which means that an experienced operator can extinguish a flammable-liquid fire with a surface of 80 square feet by means of a 30-pound extinguisher. Wheeled or truck-mounted units of 300 pounds capacity can subdue a 600-square-foot liquid fire. Monnex dry chemical is more effective than Purple K and could control fires larger than those mentioned here.

When the burning surface exceeds that area, foam must be used. Regardless of the type of foam used, the foam must be applied to flow gently over the burning surface. If the fire is a ground spill, the foam should be bounced off the ground in front of the fire. If it is an open tank fire, the foam stream should be directed against the inside wall of the tank so it will not churn the burning liquid. Spray application of foam can also be used in both situations, if the nozzle has a spray position.

Ordinary foams are not effective on alcohols, esters, or ketones. Fires in these liquids call for a special foam commonly known as "alcohol foam."

Some mechanical foams are known as 3 percent foams; others as 6 percent. As would be expected from the terminology, 3 percent means three gallons of foam to 97 gallons of water, and 6 percent means six gallons of foam to 94 gallons of water. This method also demands that the three components of a foam system be compatible for making and applying mechanical foam: the foam solution, the foam proportioner, and the nozzle. When these are mixed, the results are not good. I repeat for emphasis that these components—especially the nozzle and the proportioner—*must* be those meant to be used together. Some proportioners can be regulated to supply different percentages of foam, and this fact should be remembered so that the correct setting is used.

Detergent foams and protein foams are not compatible and, if applied to the same surface, may defeat each other. Remember that water streams should not be applied with foam streams, because the water will remove or dilute the foam blanket.

Tank Fires

Storage tank fires present a somewhat different problem from spill fires. Large tanks may be involved, and the fire may have spilled into the diked areas usually found around such tanks. Heated tanks may explode due to the pressure within them; such explosions will release large quantities of burning vapors. It is not the pressure of the explosion, but the release of burning vapors that has killed firefighters at several oil storage fires.

If the storage tanks are vertical, this hazard—although it exists—is not as great as with tanks mounted horizontally. The classic hazard of horizontal tanks is that the end of a tank will blow out, releasing a vast amount of burning liquid which, traveling much faster than anyone can run, will expand over a large area.

Vertical tanks are usually designed with a roof which has weak seams which gave way under a pressure build-up to allow the fire to vent upward—the least harmful direction. But the roof can travel for a short distance when it blows off, and this fact should be remembered.

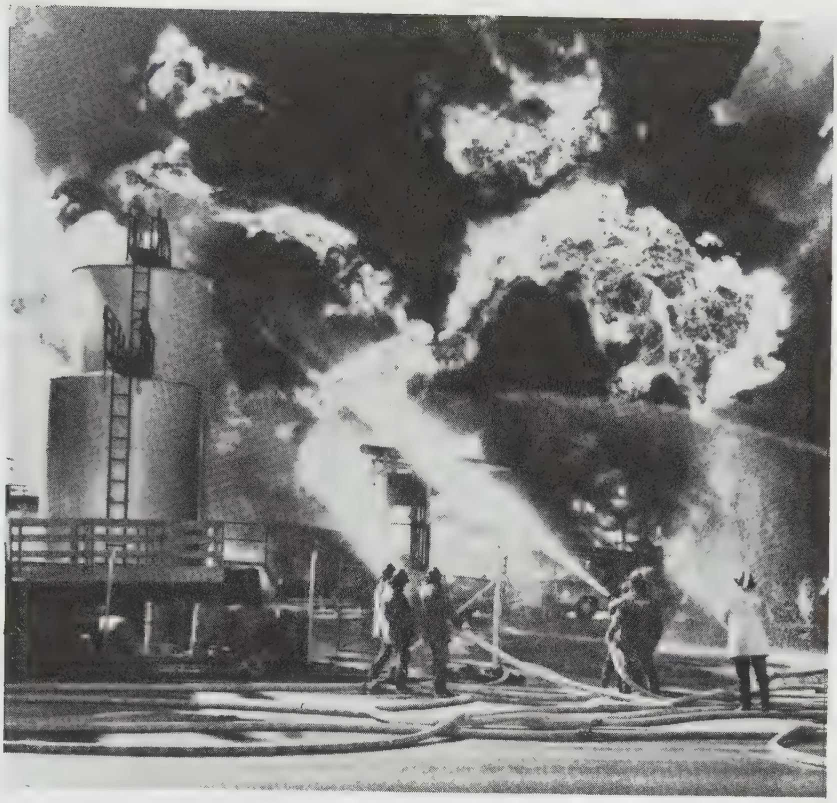


Figure 16.19. *Las Vegas firefighters controlled the fire in this gasoline storage tank with a capacity of 200,000 gallons.*

Commonly, the procedure used on tank fires is to cool the tank by applying large volumes of water to its exterior. This cooling is done to exposed tanks to keep their contents from igniting and to burning tanks to slow down the burning of their contents (Figure 16.19).

There have been occasions where firefighters have been killed by boil-over or slop-over from a large vertical tank. Boil-over will only occur in crude oil, not refined products; it occurs just as does the boiling of water in a saucepan.

Slop-over can happen with any oil product if water has been put into the tank in sufficient quantity to cause overflow. It is also remotely possible that added water collecting on the bottom of the tank will become heated from above by the burning oil and reach its boiling point, thus causing a boil-over of sorts.

Boil-over and slop-over can occur suddenly. An entire company (Engine 251) was wiped out this way at a fire in a Brooklyn oil storage yard. Therefore, avenues of ready escape should be kept open.

It is believed that the breakdown of a foam blanket on top of oil in a tank can be reduced by cooling the contents of the tank with water streams applied to the outside of the tank shell. Cooling the oil should reduce its vaporization, thus reducing the fuel (vapor) available for burning.

Some oil tanks have a built-in piping system that permits foam to be applied to the interior of a tank at the bottom. Others have a hydraulically raised portable foam tower designed to be placed alongside the tank on fire and raised to a height from which a gooseneck nozzle can be placed over the top of the tank and foam applied. Some of these are equipped with a Moeller tube, a short non-combustible hose which will unroll when the foam is forced through it and float on the surface of the liquid to permit a gentle discharge of the foam. Experiments have shown that foam can be applied through a ladder pipe, which can be advantageous not only on tanks but other elevated locations.

Another extinguishing method, used in some oil yards and about which firefighters can learn through pre-fire surveys, is the air agitation method. Air is introduced to the bottom of the oil tank to force the cool oil from its bottom to its top. This process reduces the vaporization of the oil by reducing the surface temperature.

Tank truck fires are similar to storage tank fires—except for location—and can be handled in a similar manner. Inasmuch as all tank trucks have horizontal tanks, possible failure of the tank ends should be borne in mind. End explosions of horizontal tanks have killed several firefighters. The burning liquid can shoot a hundred feet or more, like a jet.

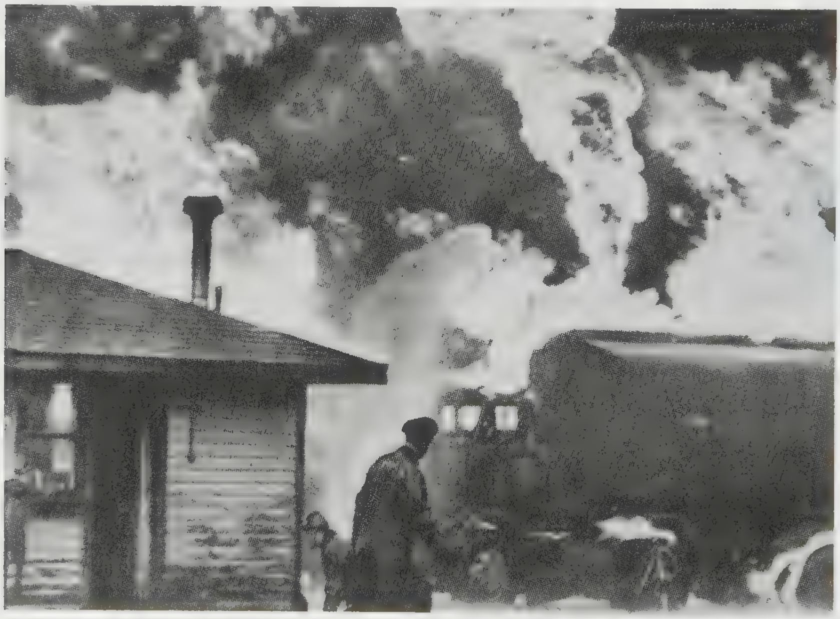


Figure 16.20. *Some tank trucks carry as much as 12,000 gallons of gasoline, which, if ignited, poses a severe threat to other vehicles on the road and occasionally to structures.*

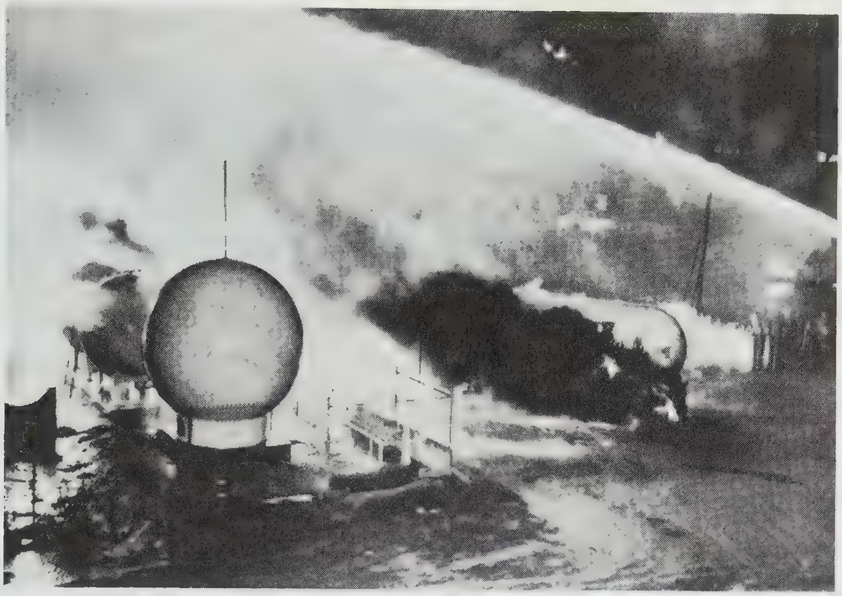


Figure 16.21. *This tank holding 15,000 gallons of propane burned for 45 minutes before the fire was extinguished. Hose streams were used to cool adjacent tanks.*

Fires within the tank can often be extinguished by the simple process of covering the dome covers. Running fires caused by valve leakage are a problem which can be solved by closing the valve from which the burning liquid is flowing, if that can be safely reached. Sometimes it can be done under cover of a fog stream.

Fog streams can be used to advantage at tank truck fires in two ways: they can drive the burning liquid away from the tank, and they can be applied to the tank to cool it.

Ha Ha MicE

Flammable Gases

There are gases that are produced for the sole purpose of being burned efficiently for heating or cooking. Sometimes these gases will ignite and burn in a hostile manner, and the fire department will be called to combat the fire.

These gases are divided into two main categories: natural gas and liquefied petroleum (LP) gas. The latter can be subdivided into propane and butane, but the principal differences are that natural gas is lighter than air and the LP gases are heavier than air. Both are explosive when mixed with the right proportion of air, and both burn readily.

When a fire involves gas in a building, the supply should be shut off at the nearest valve. Sometimes the gas will burn at the meter and, if this fire is extinguished, a build-up of gas will take place, resulting in an explosion if an ignition source, such as a smoldering remnant of the fire, is present. Therefore, it is wise to allow the gas to burn at such a leak until the valve controlling it can be shut.

If the gas is burning at a leak in the street, it is well to let it burn until it can be shut off by a crew from the gas company. Sometimes such a fire can threaten nearby buildings (I saw one such fire go to a third alarm), but the safest procedure is to protect those buildings from the fire until the gas can be shut off. Extinguishing the fire without stopping the leak can lead to an explosion.

If the fire department is called to a serious gas leak without a fire, several steps should be taken to prevent a fire from happening and to minimize its effect if it does happen. These steps include removing people from the area and eliminating possible sources of ignition such as oil burners, pilot lights, other flames, and operating internal combustion engines, including those on fire apparatus.

Hose lines should be placed and charged to protect nearby property if ignition should occur. The gas company should be notified immediately.

In extreme cases, it may be well to cut off electricity to the area to prevent ignition by sparking of an electric switch. If automobiles must be moved, it may be better to push them than to start their motors.

Whenever gas is shut off and turned on later, all open jets will emit unburned gas. Therefore, all jets should be closed in the affected area before the service is restored. Also, pilot lights will have to be reignited.

It should go without saying that smoking is forbidden in the area of a gas leak.

Leaks Caused by Natural Gas

Where natural gas has been substituted for manufactured gas, there has been a history of leakage followed by fire. Natural gas is not nearly as moist as manufactured gas, and consequently gaskets and caulking dry out and leaks begin. It is not uncommon for such leaks to occur in the streets and for the gas to follow the natural crevices in the earth or the perimeter around water or sewer pipes until it flows into a basement and reaches a source of ignition. I have seen cases where this leakage continued until the explosive mixture had permeated an entire building. In one such case in Brooklyn, when we arrived on the scene there was fire throughout the second floor of a two-story brick building, and gas was burning through cracks in the sidewalk.

Liquefied petroleum gas (LPG) is usually used in non-metropolitan areas where it is delivered by tank truck and stored on the

Railroad TANK CARS
1/2" steel welded
Head Shield Propane Tank Cars

500gpm minimum

user's premises either above ground or in buried tanks. When it leaks, there is a visible cloud, but fire officers should not be deceived into thinking that the visible vapor is the extent of the flammable area; an invisible danger zone extends beyond the visible cloud.

The gas can be dissipated by water spray streams, and such streams can be used to keep the gas away from danger spots.

Dry chemical can extinguish LPG fires, but they should not be extinguished unless a valve can then be reached to close the leak.

Inasmuch as LPG is usually stored in tanks or cylinders above ground, these containers can be cooled by hose streams. Portable cylinders should be kept upright so that the escaping product is in vapor form. An inverted cylinder would allow liquefied gas to escape, giving a far greater concentration. Sometimes a leak can be stopped by crimping copper tubing with pliers.

The bulk storage of LPG is normally in horizontal tanks above ground. Ignition of the contents of these tanks is usually caused by the heat from another source, most often a fire in an LPG tank truck. The tank fire is ordinarily at the relief valve, where the gas escapes due to the pressure created by the heat from the other fire. The danger with this type of fire—and any similar gas or liquid fire—lies mainly in the heat radiating from the relief valve flame. It impinges on the tank and can cause a rupture through the weakening of the tank combined with a pressure increase.

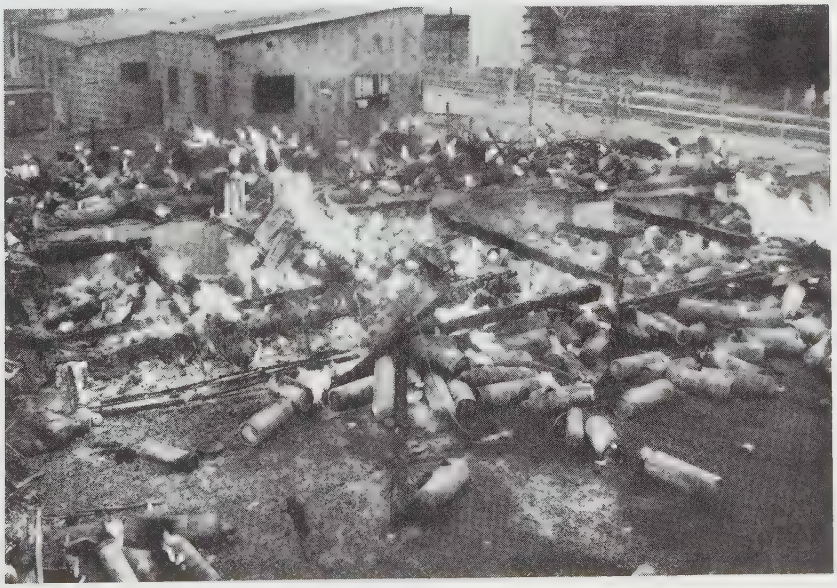


Figure 16.22. *Dozens of acetylene cylinders continue to give off flame following an explosion and fire that razed the building in which they were stored. Most of the burning is at relief valves.*

What has been said of storage tanks applies also to transportation tanks on trucks or railroad cars. If there is a leak without fire, the area should be evacuated to a reasonable distance. There have been some extreme evacuation cases reported, including a town across the Mississippi River, a few miles from the leak on a railroad car. Although any doubt should be resolved on the side of safety, evacuation doesn't have to go that far. The factors to consider are that gas moves downgrade and with the wind and can be ignited up to 200 feet beyond the visible vapor cloud.

Unless there is a compelling reason, a leaking cylinder should not be moved. If it is necessary to move it, keep it in an upright position.

In any LPG fire, the valve which controls the burning gas should be shut off if possible. In some cases, it can be reached by a firefighter who is protected by fog streams. In extreme emergencies for the saving of life or other important reasons, dry chemical may be used to extinguish the fire. There is no doubt of the ability of dry chemical to extinguish a gas fire; the question is the advisability of stopping the fire and letting the escaping gas accumulate to the point where it might cause a disastrous explosion.

PYROPHORIC METALS

Most metals will burn if they become hot enough. If they are in a finely divided state, such as shavings or powder, they will ignite easily. Metallic dusts in suspension can explode.

Ordinary metals such as iron, steel, copper, and aluminum do not present much of an extinguishment problem. When cooled with water, they will cease burning. There are, however, other metals, known as pyrophoric metals, which are not easily extinguished.

One of the most common is magnesium. It has a high ignition temperature (1,200°F) and, when it ignites, water will not extinguish the fire. In fact, it burns at temperatures so high (5,500°F) that water breaks down into hydrogen and oxygen, thus adding to the fire. Water spray will protect surrounding materials from ignition without agitating the fire. A straight stream directed on burning magnesium will cause a violent eruption, with loud reports and showers of sparks, but it will hasten the time to the end of the fire by speeding up the burning.

It is widely believed that water cannot extinguish a magnesium fire. Yet there have been cases reported, in Los Angeles and Chicago, where the heavy application of water extinguished fire in magnesium ingots.

Ordinarily the extinguishing procedure for small magnesium fires is to cover the burning metal with a powder made just for that purpose. Such powders under various names, are earth minerals which are usually shoveled on to the burning magnesium to cover it completely and smother the fire. There are other agents which form a refractory coating on the metallic surface; one of these is sodium chloride (common table salt), which is marketed in a fire extinguisher. It cakes on the surface of the magnesium.

Another extinguishing agent reported to be effective on magnesium fires is trimethoxyboroxine (TMB). It is a flammable liquid which burns gently and applies a thick, glass-like coating on the metal, thus excluding oxygen.

Other pyrophoric metals which may be encountered are lithium and zirconium. Agents have been developed for incipient fires in these metals. Lith-X, a graphite-base powder which is available in extinguishers, is reported to be effective on fires in zirconium and titanium, as well as lithium.

Of course, the extinguishing agents mentioned above are not usually available in quantities adequate for more than incipient fires. Larger fires will still require water to protect the surrounding area while the metal burns away. When water is applied to the metal, it should be remembered that straight streams will cause violent reactions. Extinguishing agents other than those mentioned may do more harm than good.

Sodium and potassium, and a combination of the two known as NAK, will also react violently with water. Small quantities may be handled with the special powders mentioned.

HAZARDOUS MATERIALS (HAZ-MATS)

The decade of the nineteen eighties was a period of increased attention to hazardous materials, including keen interest by the federal government. Congress passed the Superfund Amendments and Reauthorization Act, known as SARA, in 1986, and the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor followed with 29 CFR, Part 1910, effective March 6, 1990. These regulations bear direct application to the fire service. The *Federal Register,* Volume 54, Number 42, of March 6, 1989, offers a model scenario to illustrate OSHA's tiered approach to training, which reads as follows:

CFR - Code of Federal Regulations.

A state trooper is on routine patrol along a highway passing through a residential and light industrial area of a large metropolitan city. Ahead in his path of travel, the trooper notices a multi-vehicle accident involving a large overturned tank truck. Immediately the trooper uses his radio to contact his dispatcher to report the accident. After letting the dispatcher know the location and type of accident, the trooper places his vehicle across the travel lanes of the highway approaching the accident site to stop traffic. While he is doing this the dispatcher is alerting the fire and rescue companies in the immediate area and dispatching an established number of fire and rescue vehicles. The trooper then surveys the accident scene from his vehicle trying to identify the type of cargo on the overturned truck. Seeing three different U.S. DOT [Department of Transportation] placards on the vehicle the trooper makes note of the four digit numbers and checks his DOT Emergency Response Guide for a summary of actions to be taken for the chemicals identified on the placards. After determining his next on-site responsibility, he recontacts his dispatcher with the additional information and secures the scene. He stays away from the immediate accident site and does not become involved in rescue or site mitigation.

While the trooper has been securing the scene, the fire and rescue units dispatched after his first radio call begin to arrive on the scene with the additional information from the trooper's second call. The officer-in-charge (OIC) of the fire/rescue response stops his vehicles in a safe location and contacts the state trooper. After determining the type of accident and vehicles involved, the OIC takes control of the scene and directs his crews to take a predetermined defensive action in controlling a leak that has begun on the tanker. The OIC then contacts the dispatcher and reports his assessment of the accident scene including the fact that the tanker is now leaking. He requests the dispatcher to send him the closest hazardous materials response team. He also asks for representatives from the shipper of the liquid and the liquid's manufacturer.

In the meantime, firefighters have established a perimeter defense of the accident scene using fire hose lines and proper personal protective equipment. They begin to evacuate surrounding homes and businesses as indicated in the Emergency Response Guide in case the leaking tanker should explode. They construct dikes and diversion pits to contain water and chemical run-off from the fire hose lines. Rescue *personnel, including emergency medical technicians, have made a preliminary assessment of the accident scene and have determined whether any individuals in the spill area are trapped in their vehicles or need immediate assistance. They report their observations to the OIC.*

A decision is made by the OIC, based upon the reports of the police officer, the emergency response crew, and the data on the DOT placards, that no rescue attempts can be made safely until such time as the leaking liquid is positively identified and controlled by the HAZMAT team. The proper local authorities are notified under the requirements of SARA Title III.

As firefighters continue to provide defensive protection of the scene and as emergency medical technicians establish a triage area for the treatment of injured passengers, the HAZMAT team arrives and begins to take control of the accident scene. Hazardous materials technicians and specialists assess the scene and plan their attack on the leaking tanker.

After equipping themselves properly, the HAZMAT team makes a final, pre-attack evaluation of the scene, including a scan of the area with appropriate monitoring equipment, and reports its findings to the fire and rescue personnel. Based upon the results of the pre-attack evaluation and determination by HAZMAT team members using monitoring equipment that the spill area is non-hazardous, rescue personnel now enter the area of the accident to provide emergency medical treatment to injured passengers and to extricate those passengers who may have been trapped in their vehicles. The HAZMAT team proceeds to the point of release and secures the leak.

After all the injured have been cared for and after the leak has been stopped, the firefighters and HAZMAT team begin to clean up the accident scene in accordance with pre-planned procedures.

All four levels of hazardous materials response have played a role in this scenario. The state trooper, the first on the scene, is the first responder awareness level. The responding HAZMAT team had both hazardous materials technicians and hazardous materials specialists. In this scenario the state trooper would have to have a sufficient amount of training, the first responding fire/rescue companies would need eight hours of training, and the HAZMAT team would need 24 hours of training. The tiered training schedule is based upon the duties and responsibilities of the individuals involved in the various levels of response illustrated in the scenario.

1-800-

But even before federal requirements were set, the fire service became enthusiastic about "haz-mats." Fire departments large and small jumped on the bandwagon with haz-mat teams, haz-mat trucks, and the like. Reams of literature have been written on the subject, so it is addressed here only in one aspect. This book is about fire, not chemical leaks or cleanup; therefore, our discussion is limited to those haz-mat incidents involving fire.

Haz-mat fires break down into two broad categories: transportation and fixed-site. Transportation includes trucks, trains, and ships, and, less frequently, planes and pipelines. Transportation fires provide limited opportunity for pre-fire planning, but certain information such as the location and strength of water supply near railroads and highways can be noted; so can access. Furthermore, the sources of information and how to reach them can be recorded. These include "Chemtrec" (Chemical Transportation Emergency Center), railroad companies, the Coast Guard, trucking companies, and so on, but much more information will have to be obtained after the incident has begun.

With respect to the fixed-site category, much information can be gathered in advance by pre-fire inspection and the "right to know" provisions of SARA Title III, and plans can be made accordingly.

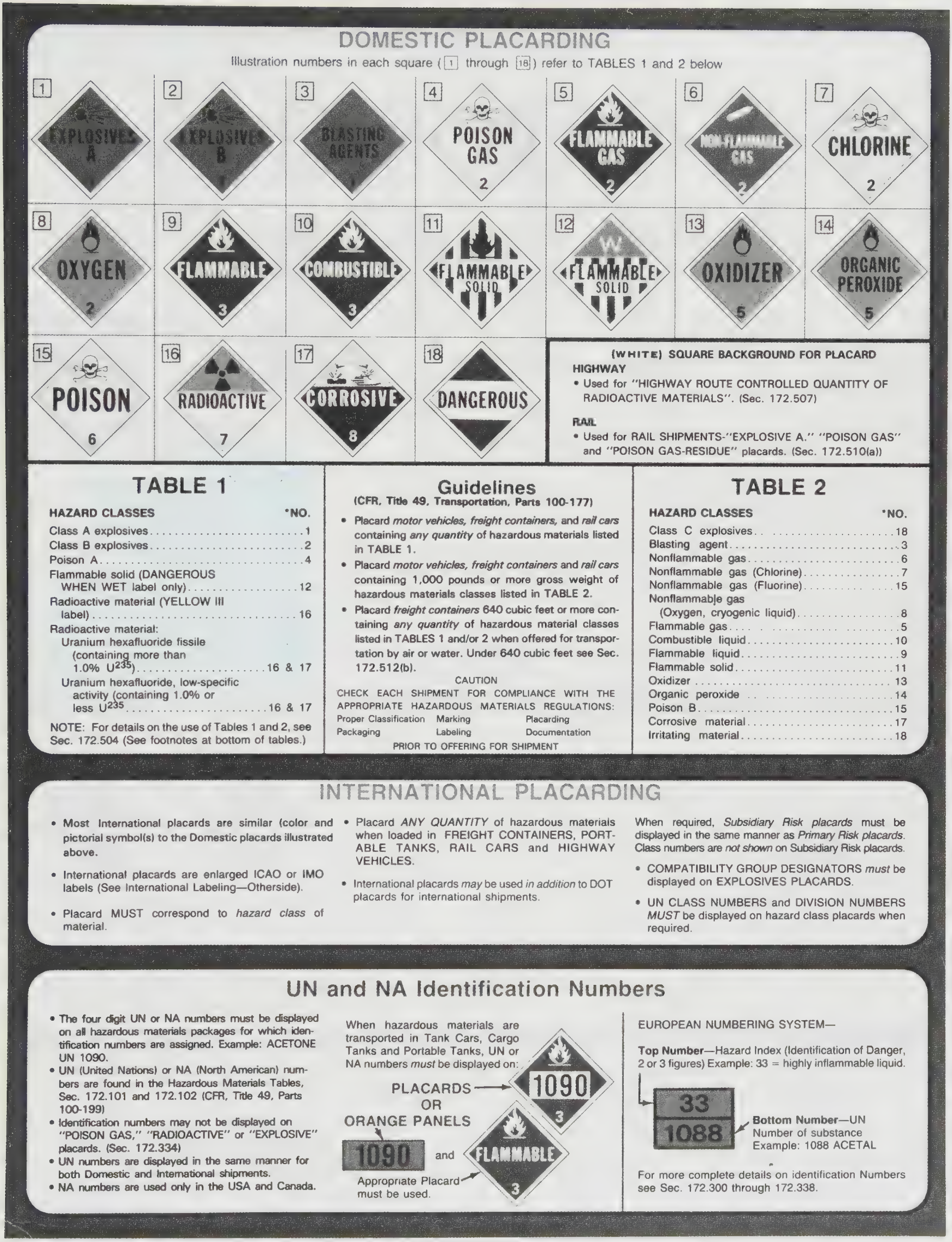
Assessment of either category begins with the usual "size-up," but with emphasis on what is burning and what is exposed. The nature of the chemical can be found from previously acquired information or from on-site observation of identification numbers or symbols (Figures 16.23, 16.24, and 16.25). Whatever method is used, an effort should be made to determine quickly what the hazards are, especially the hazards to life when this material is burning. Will it explode? Will it emit toxic fumes? Will it react unfavorably with water?

Further questions involve effects on the environment. In one midwestern community, it was decided, after due deliberation, to let the fire burn rather than cause contamination with the water run-off.

Of course, the principal concern is hazard to life, which could be immediate (explosion) or potential (toxic fumes over a residential area). Evacuation of an area is seldom necessary but often ordered. The incident commander should weigh all considerations carefully before making a decision to evacuate. If the answer is yes, the procedure should be carried out according to an orderly plan, which should have been established in advance. The police department is the agency most appropriate to accomplish area evacuation.

The incident commander is not expected to have intimate knowledge of all hazardous materials, but every fire chief should try to obtain advance information on any significant storage in his jurisdic-

1 —
2 - 4 digit #
3 - Pictogram
4 - Haz Class


1
EXPLOSIVES A
1
2
EXPLOSIVES B
1
3
BLASTING AGENTS
1
4
POISON GAS
2
5
FLAMMABLE GAS
2
6
NON-FLAMMABLE GAS
2
7
CHLORINE
2
8
OXYGEN
2
9
FLAMMABLE
3
10
COMBUSTIBLE
3
11
FLAMMABLE SOLID
12
W
FLAMMABLE SOLID
13
OXIDIZER
5
14
ORGANIC PEROXIDE
5
15
POISON
6
16
RADIOACTIVE
7
17
CORROSIVE
8
18
DANGEROUS
PLACARDS
OR
ORANGE PANELS
1090
3
1090
and
FLAMMABLE
3
Appropriate Placard must be used.
33
1088

DOMESTIC PLACARDING

Illustration numbers in each square (1 through 18) refer to TABLES 1 and 2 below

(WHITE) SQUARE BACKGROUND FOR PLACARD

HIGHWAY

- Used for "HIGHWAY ROUTE CONTROLLED QUANTITY OF RADIOACTIVE MATERIALS". (Sec. 172.507)

RAIL

- Used for RAIL SHIPMENTS-"EXPLOSIVE A," "POISON GAS" and "POISON GAS-RESIDUE" placards. (Sec. 172.510(a))

TABLE 1

HAZARD CLASSES	*NO.
Class A explosives	1
Class B explosives	2
Poison A	4
Flammable solid (DANGEROUS WHEN WET label only)	12
Radioactive material (YELLOW III label)	16
Radioactive material:	
Uranium hexafluoride fissile (containing more than 1.0% U^{235})	16 & 17
Uranium hexafluoride, low-specific activity (containing 1.0% or less U^{235}	16 & 17

NOTE: For details on the use of Tables 1 and 2, see Sec. 172.504 (See footnotes at bottom of tables.)

Guidelines

(CFR, Title 49, Transportation, Parts 100-177)

- Placard *motor vehicles, freight containers,* and *rail cars* containing *any quantity* of hazardous materials listed in TABLE 1.
- Placard *motor vehicles, freight containers* and *rail cars* containing 1,000 pounds or more gross weight of hazardous materials classes listed in TABLE 2.
- Placard *freight containers* 640 cubic feet or more containing *any quantity* of hazardous material classes listed in TABLES 1 and/or 2 when offered for transportation by air or water. Under 640 cubic feet see Sec. 172.512(b).

CAUTION

CHECK EACH SHIPMENT FOR COMPLIANCE WITH THE APPROPRIATE HAZARDOUS MATERIALS REGULATIONS:

Proper Classification	Marking	Placarding
Packaging	Labeling	Documentation

PRIOR TO OFFERING FOR SHIPMENT

TABLE 2

HAZARD CLASSES	*NO.
Class C explosives	18
Blasting agent	3
Nonflammable gas	6
Nonflammable gas (Chlorine)	7
Nonflammable gas (Fluorine)	15
Nonflammable gas (Oxygen, cryogenic liquid)	8
Flammable gas	5
Combustible liquid	10
Flammable liquid	9
Flammable solid	11
Oxidizer	13
Organic peroxide	14
Poison B	15
Corrosive material	17
Irritating material	18

INTERNATIONAL PLACARDING

- Most International placards are similar (color and pictorial symbol(s) to the Domestic placards illustrated above.
- International placards are enlarged ICAO or IMO labels (See International Labeling—Otherside).
- Placard MUST correspond to *hazard class* of material.
- Placard *ANY QUANTITY* of hazardous materials when loaded in FREIGHT CONTAINERS, PORTABLE TANKS, RAIL CARS and HIGHWAY VEHICLES.
- International placards *may* be used *in addition* to DOT placards for international shipments.

When required, *Subsidiary Risk placards* must be displayed in the same manner as *Primary Risk placards.* Class numbers are *not shown* on Subsidiary Risk placards.

- COMPATIBILITY GROUP DESIGNATORS *must* be displayed on EXPLOSIVES PLACARDS.
- UN CLASS NUMBERS and DIVISION NUMBERS *MUST* be displayed on hazard class placards when required.

UN and NA Identification Numbers

- The four digit UN or NA numbers must be displayed on all hazardous materials packages for which identification numbers are assigned. Example: ACETONE UN 1090.
- UN (United Nations) or NA (North American) numbers are found in the Hazardous Materials Tables, Sec. 172.101 and 172.102 (CFR, Title 49, Parts 100-199)
- Identification numbers may not be displayed on "POISON GAS," "RADIOACTIVE" or "EXPLOSIVE" placards. (Sec. 172.334)
- UN numbers are displayed in the same manner for both Domestic and International shipments.
- NA numbers are used only in the USA and Canada.

When hazardous materials are transported in Tank Cars, Cargo Tanks and Portable Tanks, UN or NA numbers *must* be displayed on:

EUROPEAN NUMBERING SYSTEM—

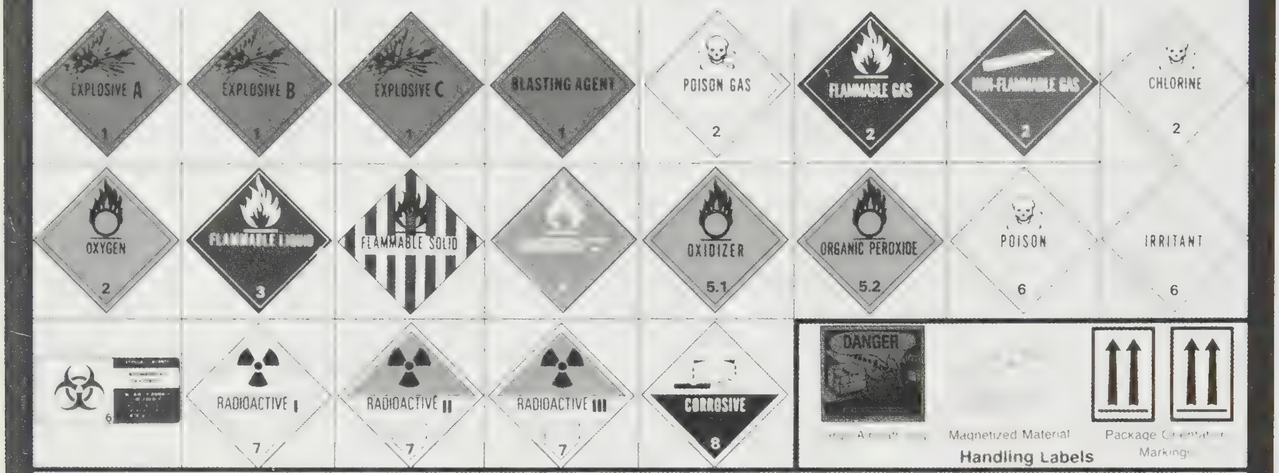
Top Number—Hazard Index (Identification of Danger, 2 or 3 figures) Example: 33 = highly inflammable liquid.

Bottom Number—UN Number of substance Example: 1088 ACETAL

For more complete details on identification Numbers see Sec. 172.300 through 172.338.

Figure 16.23. *Hazardous materials warning placards.*

DOMESTIC LABELING


EXPLOSIVE A
1
EXPLOSIVE B
1
EXPLOSIVE C
1
BLASTING AGENT
1
POISON GAS
2
FLAMMABLE GAS
2
NON-FLAMMABLE GAS
2
CHLORINE
2
OXYGEN
2
FLAMMABLE LIQUID
3
FLAMMABLE SOLID
OXIDIZER
5.1
ORGANIC PEROXIDE
5.2
POISON
6
IRRITANT
6
6
RADIOACTIVE I
7
RADIOACTIVE II
7
RADIOACTIVE III
7
CORROSIVE
8
DANGER
Magnetized Material
Package Orientation Markings
Handling Labels

General Guidelines on Use of Labels

(CFR, Title 49, Transportation, Parts 100-177)

- Labels illustrated above are normally for *domestic shipments*. However, some air carriers *may* require the use of International Civil Aviation Organization (ICAO) labels
- Domestic Warning Labels *may* display UN Class Number, Division Number (and Compatibility Group for Explosives only.) Sec. 172.407(g).
- Any person who offers a hazardous material for transportation MUST label the package, if required. [Sec. 172.400(a)].
- The Hazardous Materials Tables, Sec. 172.101 and 172.102, identify the proper label(s) for the hazardous materials listed.
- Label(s), when required, must be printed on or affixed to the surface of the package near the proper shipping name. [Sec. 172.406(a)]
- When two or more different labels are required, display them next to each other. [Sec. 172.406(c)].
- Labels may be affixed to packages (even when not required by regulations) provided each label represents a hazard of the material in the package. [Sec. 172-401].

Check the Appropriate Regulations

Domestic or International Shipment

UN Class Numbers

Class 1—Explosives

Class 2—Gases (compressed, liquified or dissolved under pressure)

Class 3—Flammable liquids

Class 4—Flammable solids or substances

Class 5—Oxidizing substances
Division 5.1-Oxidizing substances or agents.
Division 5.2-Organic peroxides.

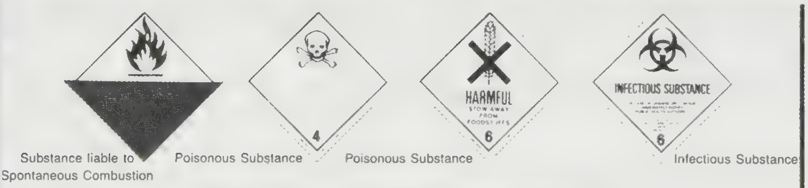
Class 6—Poisonous and infectious substances

Class 7—Radioactive substances

Class 8—Corrosives

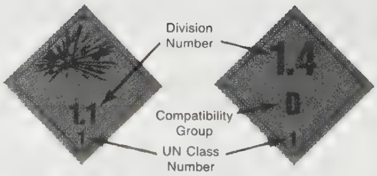
Class 9—Miscellaneous dangerous substances

INTERNATIONAL LABELING


4
HARMFUL
STOW AWAY FROM FOODSTUFFS
6
INFECTIOUS SUBSTANCE
6
Substance liable to Spontaneous Combustion
Poisonous Substance
Poisonous Substance
Infectious Substance

EXAMPLES OF INTERNATIONAL LABELS

- These are examples of International Labels not presently used for domestic shipments.
- Text, when used Internationally *may* be in the language of the country of origin.
- Most of the domestic labels (illustrated above) *may* be used Internationally.


Division Number
1.1
1
1.4
D
1
Compatibility Group
UN Class Number

EXAMPLES OF EXPLOSIVE LABELS

- The NUMERICAL DESIGNATION represents the CLASS or DIVISION.
- ALPHABETICAL DESIGNATION represents the COMPATIBILITY GROUP (for Explosives Only)
- DIVISION NUMBERS and COMPATIBILITY GROUP combinations can result in over 30 different "Explosives" labels (see IMDG Code/ICAO).

For complete details, refer to one or more of the following:

- Code of Federal Regulations, Title 49, Transportation. Parts 100-199. [All Modes]
- International Civil Aviation Organization (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by air. [Air]
- International Maritime Organization (IMO) Dangerous Goods Code. [Water]
- "Transportation of Dangerous Goods Regulations" of Transport Canada. [All Modes]

U.S. Department of Transportation

Research and Special Programs Administration

Washington, D.C. 20590

CHART 8
REV. FEBRUARY 1986

Figure 16.24. Hazardous materials warning labels.

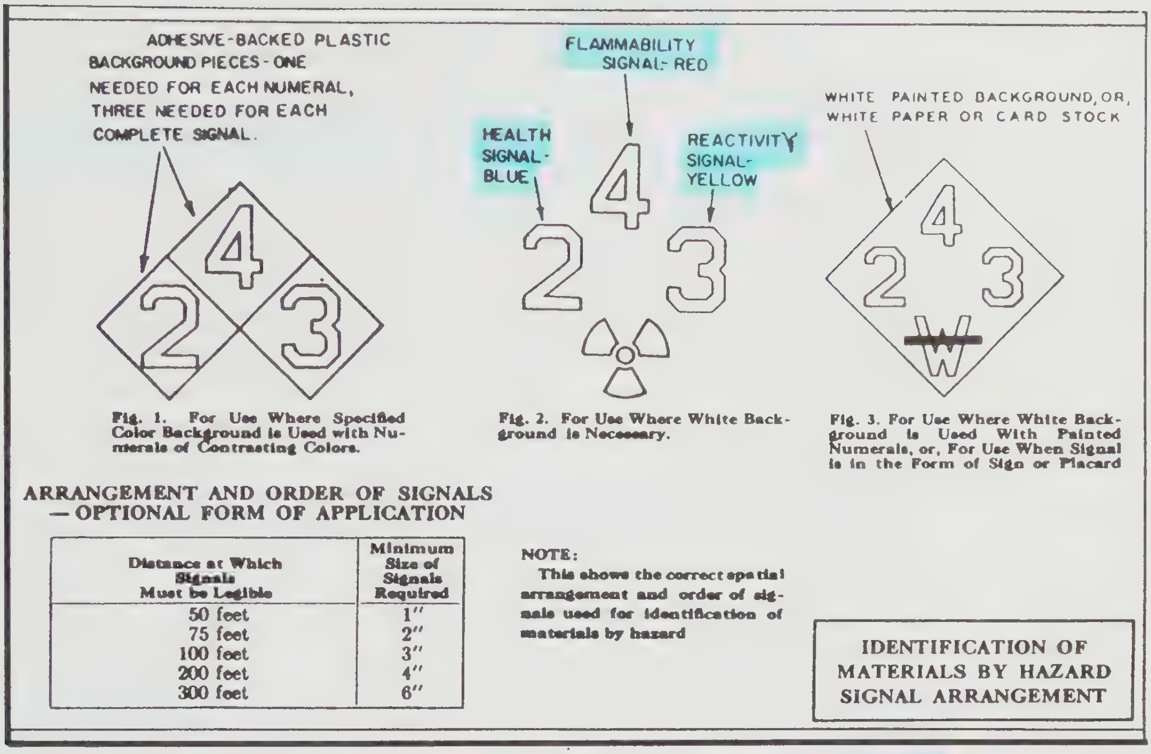

ADHESIVE-BACKED PLASTIC BACKGROUND PIECES - ONE NEEDED FOR EACH NUMERAL, THREE NEEDED FOR EACH COMPLETE SIGNAL.
4
2
3
FLAMMABILITY SIGNAL- RED
HEALTH SIGNAL- BLUE
REACTIVITY SIGNAL- YELLOW
WHITE PAINTED BACKGROUND, OR, WHITE PAPER OR CARD STOCK
W

Fig. 1. For Use Where Specified Color Background is Used with Numerals of Contrasting Colors.

Fig. 2. For Use Where White Background is Necessary.

Fig. 3. For Use Where White Background is Used With Painted Numerals, or, For Use When Signal is in the Form of Sign or Placard

ARRANGEMENT AND ORDER OF SIGNALS — OPTIONAL FORM OF APPLICATION

Distance at Which Signals Must be Legible	Minimum Size of Signals Required
50 feet	1″
75 feet	2″
100 feet	3″
200 feet	4″
300 feet	6″

NOTE:
This shows the correct spatial arrangement and order of signals used for identification of materials by hazard

IDENTIFICATION OF MATERIALS BY HAZARD SIGNAL ARRANGEMENT

Figure 16.25. A. Identifying materials by hazard signal arrangement (from NFPA Standard 704). Fixed Facilities

Identification of Health Hazard Color Code: BLUE		Identification of Flammability Color Code: RED		Identification of Reactivity (Stability) Color Code: YELLOW	
	Type of Possible Injury	Susceptibility of Materials to Burning		Susceptibility to Release of Energy	
Signal		Signal		Signal	
4	Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment were given.	4	Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature, or which are readily dispersed in air and which will burn readily.	4	Materials which in themselves are readily capable of detonation or of explosive decomposition or reaction at normal temperatures and pressures.
3	Materials which on short exposure could cause serious temporary or residual injury even though prompt medical treatment were given.	3	Liquids and solids that can be ignited under almost all ambient temperature conditions.	3	Materials which in themselves are capable of detonation or explosive reaction but require a strong initiating source or which must be heated under confinement before initiation or which react explosively with water.
2	Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment is given.	2	Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur.	2	Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. Also materials which may react violently with water or which may form potentially explosive mixtures with water.
1	Materials which on exposure would cause irritation but only minor residual injury even if no treatment is given.	1	Materials that must be preheated before ignition can occur.	1	Materials which in themselves are normally stable, but which can become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently.
0	Materials which on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.	0	Materials that will not burn.	0	Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.

B. Identifying materials by number and color of signal.

tion. It is surprising how often he will receive conflicting information from experts after the fire starts. When the answers to long-distance phone calls do not agree on proper procedures, it can be disconcerting.

Positive identification is not always obtainable, especially at transportation fires. An actual case occurred in which the railroad authorities gave the fire department incorrect identification of the material in a tank car fire, and the mistake was not revealed until days later. Fortunately, the error did not affect the incident's outcome.

Where contamination is a threat, the practice is to establish three zones. The area where contamination is likely is designated the "HOT" zone. Adjacent to that is an area called the "WARM" zone, and the perimeter—at a distance far enough to be safe without breathing apparatus or other special equipment—is called the "COLD" zone.

Travel from one zone to another should be carefully controlled, with limited entrance to and exit from the "HOT" zone. The "WARM" zone should be monitored for contamination of personnel and equipment, and decontamination carried out there before re-entry to the "COLD" zone. The command post, staging area, and ancillary activities should be restricted to the "COLD" zone, and preferably be located upwind from the "HOT" zone.

In addition to the federal regulations, there are helpful guides such as NFPA 470 and the U.S. Department of Transportation's *Emergency Response Guidebook*. There are also several excellent texts specifically intended for the fire service. On-scene advice can be obtained by telephoning "Chemtrec," which is a center for emergency information on chemicals, and perhaps from the manufacturer of the material.

If the situation escalates in size or importance, the incident command system can be initiated and expanded as needed.

CHEMICAL FIRES

Because so many available chemicals burn, it would be impractical to study them here in depth. Some guidelines on when not to use water have already been given earlier in this book. Long lists of chemicals and their characteristics are available in other publications.

Chemical hazards at fires manifest themselves in several forms:

1. Explosion from heating
2. Dangerous reaction with water
3. Corrosive action
4. Toxicity

Peroxides

Some peroxides, because of their ability to release oxygen, can be explosive alone and in combination. Hydrogen peroxide, for example, can release oxygen and explode violently at elevated temperatures. Sodium and strontium peroxide react with water to release heat and oxygen, thus providing two sides of the fire triangle. If a fuel is also present, intense fire will occur. Barium peroxide mixed with organic material can cause an explosion when wet.

Nitrates

Nitrates can be highly explosive under certain conditions. One of the largest explosions in United States history was the blast of ammonium nitrate during a fire in the hold of a ship at a pier in Texas City, Texas, on April 16, 1947. This disaster killed 468 people, including the entire on-duty force of Texas City firefighters, and leveled a sizeable portion of the waterfront area. Ammonium nitrate is commonly used as a fertilizer and is harmless when stored alone and away from organic materials, but when mixed with them, its hazard can be severe. For instance, ammonium nitrate mixed with fuel oil is used as a common blasting agent in rural areas. It was this combination which was used to blow up a building at the University of Wisconsin, and which killed six firefighters in Kansas City, Missouri, in 1989.

Potassium nitrate and sodium nitrate will not themselves burn, but they will release much oxygen when heated and will form an explosive compound when mixed with organic material.

Other oxidizers include nitrites, chlorates, and hypochlorates, all of which can evolve large quantities of oxygen and can cause explosions under certain circumstances.

Water can be applied to the chlorates, nitrates, nitrites, and hypochlorates, but not the peroxides or anhydrides, which can react violently with water.

The toxicity of gases and vapors is a hazard encountered frequently at fires. Sometimes the problem stems from a substance which is a gas in its natural state. At other times it is caused by vapors given off by a material that is not normally found in the gaseous state.

Ammonia

Ammonia (which is lighter than air) can ignite and even explode, but it seldom does. In most fires involving ammonia, the problem is not the ignition of the ammonia but the irritating effects that the gas has on the human respiratory tract, eyes, and skin. In addition to breathing apparatus, complete coverage of the body by rubberized material is needed for work in heavy concentrations of ammonia fumes. Ammonia is readily absorbed by water, and spray streams provide an effective means of absorbing it.

Places where ammonia is used in large quantities should have safety devices similar to those required by the New York Fire Department. These devices include a readily accessible valve (on the building's exterior) and siamese connection. The fire department can connect a hose line to the siamese, start water, open the valve, and purge the ammonia from the system into a sewer. Officers should learn the locations of these ammonia mixers and the water flow requirements for them.

Chlorine

Chlorine, a gas that is heavier than air, is extremely irritating. It is usually stored under pressure in metal cylinders, which have relief valves that may open when the cylinders are heated by a fire. Breathing apparatus will be necessary for survival in concentrations of chlorine gas.

Hydrocyanic Acid

Hydrocyanic acid is one of the most dangerous gases a firefighter may encounter, and the chances of encountering it are not as remote as some might think. This gas is used for large-scale fumigation in places such as warehouses and ships. Very small concentrations can be rapidly fatal and, even if breathing apparatus is worn, the gas can be absorbed through the skin. Whenever hydrocyanic acid gas is used for fumigation, the building should be placarded and the fire department notified. This information should be posted prominently on fire station bulletin boards in the district affected.

Hydrogen Sulfide

Hydrogen sulfide is not only highly toxic, but it can burn or explode. Fire in a truckload of hydrogen sulfide in the Holland Tunnel beneath the Hudson River took the life of a New York City battalion chief and led to more stringent regulation of the transportation of hazardous materials through vehicular tunnels.

Nitrogen Oxides

Nitrogen oxides are vapors given off by the burning of nitrocellulose materials. When I joined the New York Fire Department, there was a general fear of nitrocellulose, which was still being used in large quantities at that time. It not only burned more fiercely than any other substance, but gave off deadly oxides of nitrogen. Celluloid was one of the first plastics and was used in eyeglass frames, small utensils, combs, brushes, ornaments, and the like. Motion picture film was also made of cellulose nitrate before today's acetate film was introduced. Fires involving such film were considered the most dangerous. I remember when a single reel of nitrocellulose film (1,000 feet, 35 mm) burned, killing one fireman and hospitalizing others. There are still many old prints of movies on nitrocellulose film in storage in archives and vaults, as well as in private possession. Other plastics have long supplanted celluloid, but pyroxylin plastics present the same hazards.

Nitrocellulose can ignite spontaneously through decomposition. It supplies its own oxygen and burns with great speed and energy release. It is so hazardous that the fire prevention code in New York City will not permit its use in manufacturing on any floor except the top floor of a building.

The presence of nitrocellulose in a fire can be detected by the color of its smoke, which is usually a light reddish brown, and its camphor-like odor. The physiological effects of the smoke are often delayed and can become fatal hours after exposure. Once I was exposed to a small amount of such smoke—it had a narcotic effect; about an hour later I was exhilarated. The world had suddenly become wonderful, and I felt impelled to sing. The feeling wore off in another hour, and there were no further effects (such as edema of the lungs, which can follow a severe exposure).

Sulfur Dioxide

Sulfur dioxide is without doubt the most irritating gas I ever inhaled, even worse than the fumes given off by heated carbon tetrachloride, which contain hydrochloric acid gas. Sulfur dioxide was the most commonly used refrigerant in household refrigerators until the 1950s and may still be encountered as a gas in refrigerators occasionally. Nowadays it is more commonly found in the vapors from burning sulfur. One cannot distinguish the smell of the refrigerant from that of burning sulfur. Once, we carried a refrigerator down four flights of stairs only to find that the fumes were coming from sulfur candles being used for fumigation. Sulfur candles are an easy-to-use, readily available means of driving cockroaches and bedbugs from one apartment to another in a tenement house. Therefore, they are frequently encountered in neighborhoods where such insects abound. The common procedure is to close all windows tightly, light the candles, and then leave for the day while the candles do their work. Sometimes, however, neighbors smell, or see, the fumes and call the fire department. Sometimes a candle starts a fire, and the fire department is called.

The candles are usually found in two places: under beds (to get rid of bedbugs) and under sinks (if cockroaches are the problem). Sulfur dioxide is rapidly lethal in low concentrations, probably even more so than carbon monoxide. No one would be able to inhale a lethal amount willingly because it is so irritating; however, I once saw a mother and two children trapped in their apartment by sulfur fumes coming from candles below. It was an odd sight to see them hanging over the window sill crying and calling for help with no fire or smoke visible. This account is mentioned here to point out that invisible gases should be suspected and breathing apparatus ordered when such a situation is encountered.

Insecticides

There are several widely used insecticides which give off highly toxic fumes when involved with fire, and firefighters have been affected by them. Whenever there are indications that insecticides are present, it should be assumed their fumes will be dangerous when inhaled. Such materials are usually found in farm supply stores and warehouses and, in lesser quantities perhaps, on farm premises.

With all of the gases or vapors mentioned above, the primary precaution is the use of self-contained breathing apparatus. Where concentrations of heavier-than-air gases are great, consideration should be given to the effects of the gases' diffusion through the surrounding area, especially downwind. Perhaps ventilation should be kept to a minimum in some cases. In others, evacuation may be necessary.

This section is not meant to be a complete treatise on chemical fire hazards. There are books which deal exclusively with this subject, and fire officers or students of firefighting are urged to read them. What have been given here are tactical considerations for different types of hazardous materials, which are applicable in a variety of fire situations. Leaks, spills, and other incidents, and medical care are not covered here, and it is recommended that such information be obtained from texts that consider these matters in detail.

Military Escort

Radio active 3
must Be placards & ENCASED.

RADIOACTIVE MATERIALS

Most radioactive materials are used in small concentrations in medical and industrial occupancies; these sites can be identified and catalogued during pre-fire inspections. The information gathered should include the material, its hazard (strength), and location. Of course, you could wait until the fire and just look out for the standard symbol of the purple, three-bladed propeller on a yellow background, but, even if the firefighters all know what it means, they may not be able to see it in a smoky atmosphere.

Sometimes, radioactive materials may be present in a transportation fire, not subject to advance data collection. The symbol might be the only indication.

Radiation is invisible, and some types of rays easily penetrate firefighters' protective clothing. Breathing apparatus may protect against one kind, but not another. Protection is afforded by time and distance. The dosage can be kept low by short exposure or greater distance.

The amount of radiation being given off can be measured by a survey meter (CD-V-715 or V-717) or a Geiger counter (CD V-700). The dosage absorbed can be measured with a dosimeter (CD-V-742). These devices can be obtained in sets from the federal government through the appropriate state agency, and training in their use can be had from the state civil defense (emergency management agency). But, like any other electronic device, these instruments need care and maintenance if they are to be relied on. Because of infrequent use, they may become neglected; some fire departments that are dismayed at citizens allowing dead batteries in their smoke detectors may allow the same situation in their radiological instruments.

AIRCRAFT FIRES

There is a widespread tendency to attack all aircraft fires with foam and to use foam almost exclusively (Figure 16.26). An actual case occurred in which the firefighting crew stuck a foam nozzle in the cockpit of a plane and filled it while the pilot was still in his seat. The interior of a plane is not greatly different from that of a bus or a railroad car, and it should not require different firefighting methods.

Foam is intended for extinguishing flammable-liquid fires. If there happens to be a fire involving flammable liquids at the site of a plane crash, then foam, if it is available, should be used on that fire.

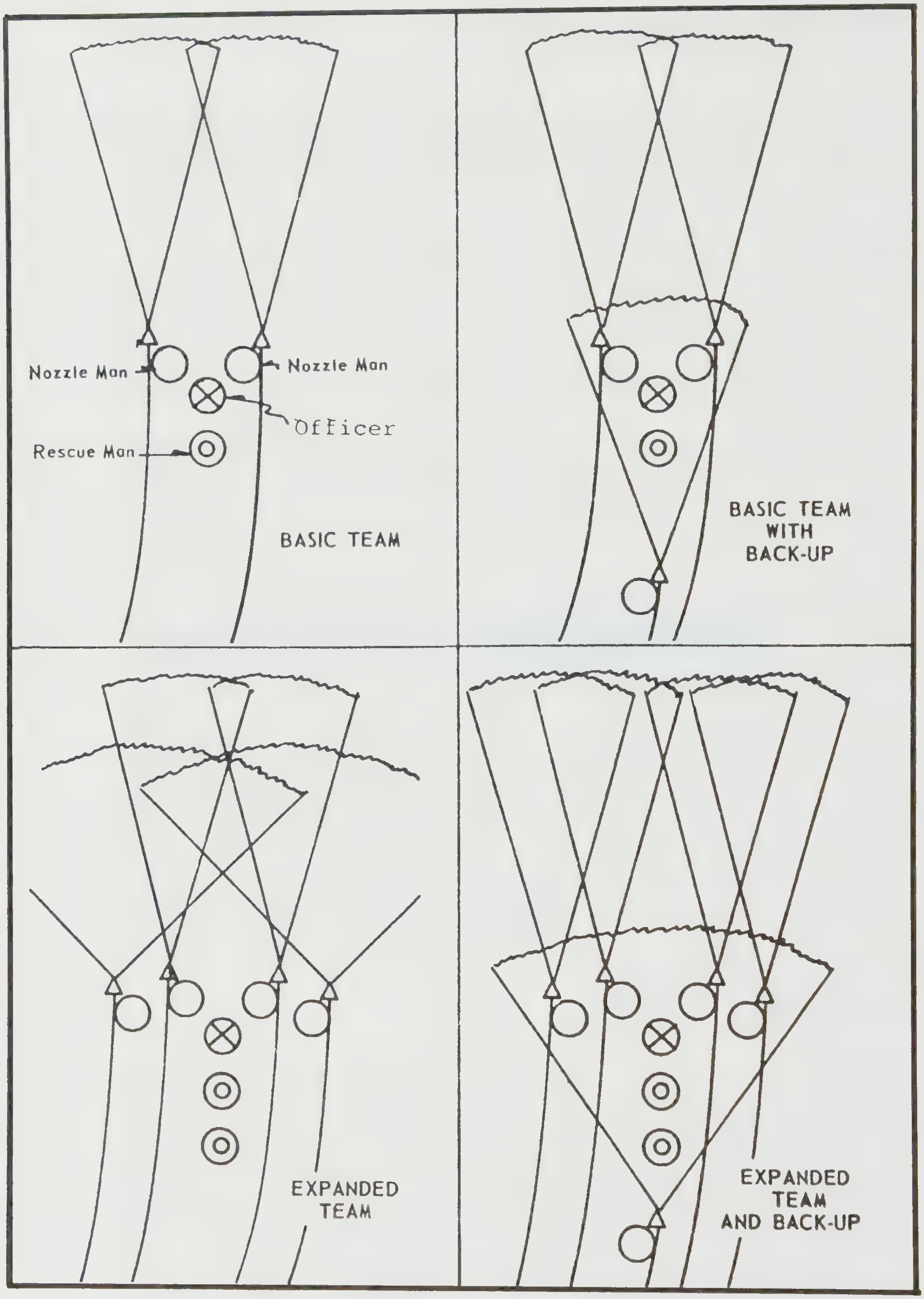

Nozzle Man
Nozzle Man
Officer
Rescue Man
BASIC TEAM
BASIC TEAM WITH BACK-UP
EXPANDED TEAM
EXPANDED TEAM AND BACK-UP

Figure 16.26. *Aircraft crash fires: team and hose line alternatives.*

Aircraft fuels fall into three categories: avgas (aviation gasoline), jet-A, and jet-B. Avgas has characteristics—including flash point—similar to high-octane automobile gasoline; jet-A is similar to kerosene or diesel fuel. Jet-B is a combination of kerosene and gasoline, more flammable than jet-A but not as much so as avgas. A jet-A fire might be extinguished with water fog, but avgas and jet-B require foam. In the absence of foam, however, fog streams may be able to contain or push back the fire to protect people or parts of the plane. The information presented here is not meant for highly trained, well-equipped airport crash crews but for firefighters responding with conventional apparatus.

Aircraft crashes fall into two categories: survivable and non-survivable. The non-survivable type follows an uncontrolled drop from a great height, and all aboard are dead before the arrival of the fire department. In a survivable crash, the airframe is relatively intact, people may have survived, and the fire department may possibly be able to save them.

Rescue approaches and procedures may vary according to circumstances. They would not be the same for a small plane with less than 40 gallons of fuel aboard as for a large commercial passenger craft with 40,000 gallons, but some principles apply in almost all cases.

1. Approach with the wind at your back. This direction allows better visibility, inflicts less punishment, and helps to carry extinguishing agents toward the fire.
2. Work as a team. Rescuers should be positioned between the hose streams, and all personnel should be stationed on the inside of the hose lines. This rule pertains to foam as well as to fog application.
3. Foam application should start at the near end of the fire and work forward.

Entry to the fuselage may be possible through regular entrances. Cabin doors possess external handles that are pulled out and turned clockwise to open the door. Directions for releasing the emergency exits require pushing in a push-panel and lifting the hatch by pushing in and up. If the entrances are jammed, perhaps they can be forced with forcible-entry tools, and, if necessary, holes can be cut in the fuselage. Mobile passengers should be evacuated first to relieve congestion.

It is important that crews advancing hose streams stay close enough so that their spray patterns overlap slightly, and that they coordinate their movements. This procedure is usually carried out by the officer keeping his hands on the nozzle operators on either side of him. Firefighters with only conventional equipment can be of significant value at aircraft fires if they use their skills and equipment to suit the occasion.

I thank Major P. Brown, Command Marshal (retired) Canadian Forces Training command, for much of this information.

FIRES IN PLACES OF ASSEMBLY

Some of the worst fires in history, from the standpoint of mass deaths, have occurred in places where large crowds gather for entertainment. Some of these have been in theaters such as the Iroquois in Chicago (602 lives lost), night clubs like the Coconut Grove in Boston (492 dead) and Southgate, Kentucky (164 fatalities), and dance halls as in Natchez, Mississippi (207 people killed).

Panic plays a big part in such disasters, and, since it usually starts before the fire department is called, much of the damage is done before the first-alarm companies arrive. Firefighters should, however, seek and open any exit not already in use, remove the dead or injured who may be clogging exits, and assist occupants to escape.

Ventilation, especially at the roof, may relieve entrapped occupants, and a quick, strong attack on the fire may save lives by removing the danger. It is difficult for all these tasks to be done simultaneously with inadequate personnel. That is why first-alarm assignments should be strong for places of assembly, and help should be called early.

Pre-fire planning should consider that escaping crowds may prevent hose lines from being taken inside because the exits are already being used for escape. Other ways to enter must be found. Points for ventilation should be selected during the pre-fire planning. Usually, stages are equipped with skylights which open by a fusible link or some other heat-actuated device, but, unless there is sufficient heat, they won't open to allow smoke to escape. Sometimes even heat won't actuate them, and they must be broken or moved manually. A newer type, which pops open forcefully, should be approached with caution.

Large auditoriums require an unusually large number of hose lengths to be taken inside the building. Allow for this need when stretching in. Long reach of streams may be necessary; therefore, nozzle pressures should be strong.

FIRES IN PLACES OF WORSHIP

Although services may vary considerably among religious denominations, the edifices in which they are conducted are remarkably similar in construction. Therefore, when we refer to church fires, we are including any building regularly used for religious services which fits the architectural description.

In church fires, the construction feature that usually leads to the church's destruction is a huge hanging ceiling or cockloft. Once fire reaches this space, it is almost sure to burn without interference because the area is virtually inaccessible. The ceiling is too high to be opened from below, the walls are too strong to be pierced, and the roof is unsafe to work upon. Furthermore, church construction often gives a fire ready access to the cockloft by way of furred wall spaces. At these fires, every effort should be made to discover and stop upward travel of the fire before it can reach the cockloft.

When there is a fire in a cockloft, an attempt to reach it can be made by placing a deluge gun in an aisle and directing a good stiff stream (held on one spot) at the ceiling in hopes that it will knock off plaster and penetrate the cockloft; however, it should be remembered in the placement of such a stream or even a hand line, that from the main entrance there is usually a vestibule about ten feet long and then, above, a choir loft of similar dimension. A nozzle would have to be advanced at least 20 feet into the main body of the church to clear the bottom of the choir loft. This technique is an extremely hazardous

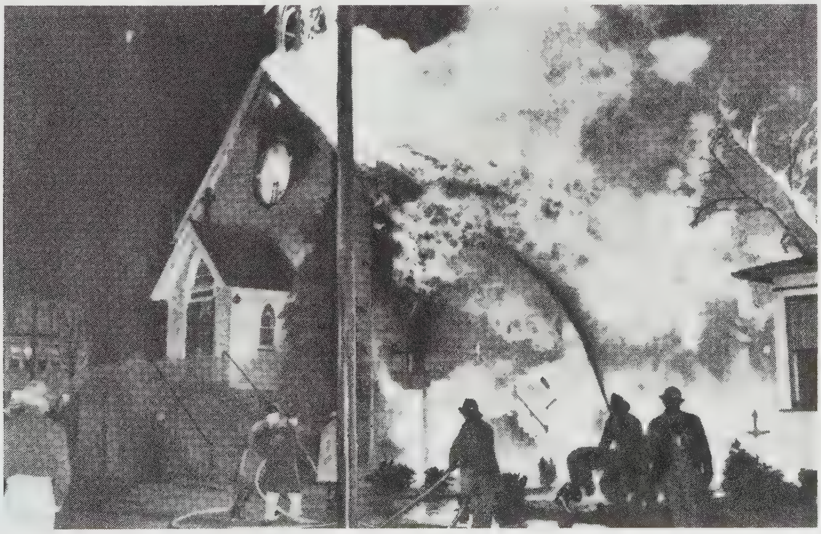


Figure 16.27. *Limited access to ceiling spaces and the danger of ceiling collapse usually rule out interior firefighting at well-advanced church fires.*

operation (because of the possibility of collapse), and firefighters, having placed the deluge gun, should immediately back out.

Sometime a louvered opening in an end wall may give access to the cockloft for an aerial stream when opened.

If the church has a steeple, fire will probably enter it and eventually cause it to collapse. The height of the steeple may require aerial streams, but, in placing the apparatus, consider the distance that the steeple may fall from the vertical. Also, the weight of a bell or bells that may be present must be considered in establishing precautions for the eventuality of its falling. Church bells are extremely heavy.

There have been cases of churches lost to fire because firefighters were reluctant to break expensive stained glass windows for needed ventilation; the fire eventually destroyed the same windows.

Many churches are connected to a rectory by an unprotected passageway through which fire can travel easily, in either direction, unless prevented by hose streams.

The life safety record for church fires is remarkably good, with hardly any multiple deaths. Of course, this statistic could be due to the fact that they are not frequently occupied, and most church fires occur when the congregation is not present.

SCHOOL FIRES

Even though fire drills are practiced regularly in schools, our fire history contains several cases of fatal school fires, and most of the schools in use today are just as vulnerable as those in which the fatal fires occurred.

One of the problems facing fire companies arriving at a school fire is confusion. When so many people are involved, it is difficult to find out if all have exited safely. Another factor is that children do not behave rationally in a severe fire situation. There have been cases where they could have dropped from second-floor windows but didn't, and even a case where they failed to escape from a first-floor classroom. Just as in dwelling fires, children tend to huddle and hide from the fire rather than flee from it. Therefore, search is most important. Ladders should be raised to every upstairs classroom. Firefighters should enter and seek the children. In some cases, they have been found just inside the windows.

Ventilation at school fires should be performed with the aim of saving life by conducting smoke and heat away from escape routes. Hose lines should be placed so as to keep the fire from entering corridors or stairways. In so doing, it may be possible to isolate the fire to one part of the building.

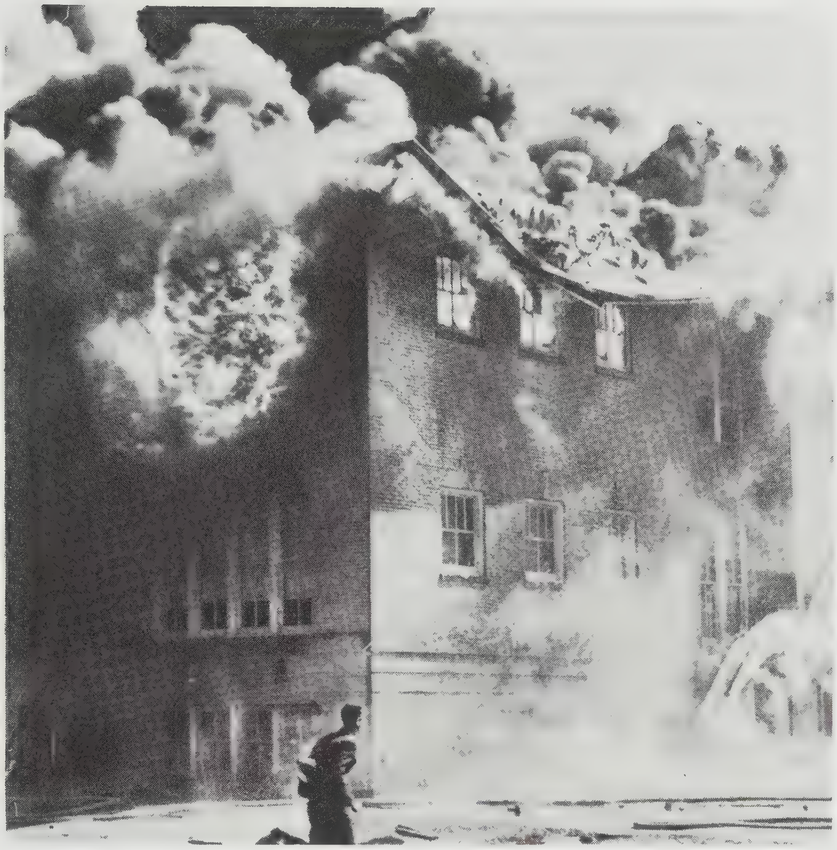


Figure 16.28. School fires may call for prompt and thorough search and rescue. At this school fire in Houston, Texas, only firefighters were injured.

A hazard in older schools is the presence of huge ventilation ducts, which, in a past era of school construction, architects deemed necessary for one reason or another. Every classroom had at least one ventilating grille, and some of the ducts serving them actually terminated in the attic. Many of these schools have been modernized and the grilles concealed, but, in most cases, the duct is still present although not always visible.

MOTOR VEHICLE FIRES

Almost one-fourth of all fires causing damage involve motor vehicles (automobiles or trucks), and a fairly sizeable portion of fire deaths occur in motor vehicles, usually after an accident. In many areas of the country, 25 percent of fire deaths are the result of such automobile accidents. A fire in an automobile can be more costly than a fire of similar size in a building—a truck and its cargo may be worth more than a house and all its contents.

Fire departments usually don't inspect automobiles and trucks, and, if they did, they would still have to contend with fires in those that are just passing through their fire district when the fire occurs. Furthermore, they have to face the fact that truck cargoes change almost daily, and, as they change, so do the hazards they present to the fire department.

The life hazard in passenger automobiles is mostly to passengers who are unable to escape from a car which has caught fire following collision. In some cases the victim is unconscious or unable to move because of his injuries; in other cases, he is trapped because the configuration of the wreckage does not allow escape. Therefore, the rescue problems differ. In the first case, quick removal may be possible, but, in the second, removal may be difficult and time-consuming, and the only way the victim can be saved from burning is by quick extinguishment of the fire. Seat belts, when fastened, may be a problem in quick removal. Therefore, a knife which can quickly and safely cut through a seat belt should be carried by all fire-fighters. Badly damaged doors are often difficult to open and may have to be forced or cut.

Inasmuch as most automobiles carry gasoline to be used for propulsion, there is always the possibility of explosion. Firefighters have been killed or badly burned by the explosion of a gas tank or the sudden ignition of leaking gasoline. I have witnessed what happened when a firefighter knocked the cap off a gasoline tank which was involved in a fire. Fire was burning around the tank on a panel truck, and a blue flame was issuing from the small vent in the gas tank cap. When the cap was knocked off, burning gasoline erupted like a volcano and chased us up the street and into a vacant lot, setting fire to rubbish in the lot, which was about 60 feet from the burning panel truck. Two firemen received minor burns.

The cap was removed to prevent an explosion of the tank by relieving the pressure. The sudden release of pressure may have prevented an explosion, but it also allowed another type of calamity. Probably if the fuel tank had been cooled from a distance, or the fire smothered, the eruption as well as the explosion could have been prevented.

There is a firmly entrenched tradition in many fire departments that the battery of a motor vehicle should be disconnected after every fire. This practice is quite valid when the cause of the fire was probably electrical, but it is of no value when the cause obviously was not electrical in origin. If, however, the cause of the fire is electrical, the battery must be disconnected or the fire will reignite. Surprisingly, many fire companies are not equipped to disconnect an automobile battery without damaging it, and, consequently, many batteries are destroyed by fire departments. An inexpensive wrench can save time and damage in disconnecting battery cables.

Fires can start in automobile upholstery from discarded cigarettes or other causes, and their complete extinguishment usually requires the removal of seat cushions. Sometimes a fire involving the under side of the vehicle will conduct sufficient heat to ignite floor mats, and a fire in the rear seat may enter the trunk. Therefore a car should be examined thoroughly to discover any remaining fire.

Now that small wing vent windows are not being installed on some new cars, other methods of light-damage entry must be sought. Tools are available, used by police and parking lot operators, which provide no-damage forcible entry in a matter of seconds.

Trucks carry various cargoes, some of which can be quite dangerous when involved in fire. They can be explosive or toxic; therefore, a truck fire involving cargo should be approached with caution. There may be no markings to identify a hazard, and the driver may not be aware of any. For instance, we received a shipment of 550 gallons of heptane in 55-gallon drums. The driver had no idea of what heptane was and was quite surprised to learn it was as explosive as gasoline. He was carrying it as part of a mixed cargo in a closed-body truck and had been given no warning or special instructions.

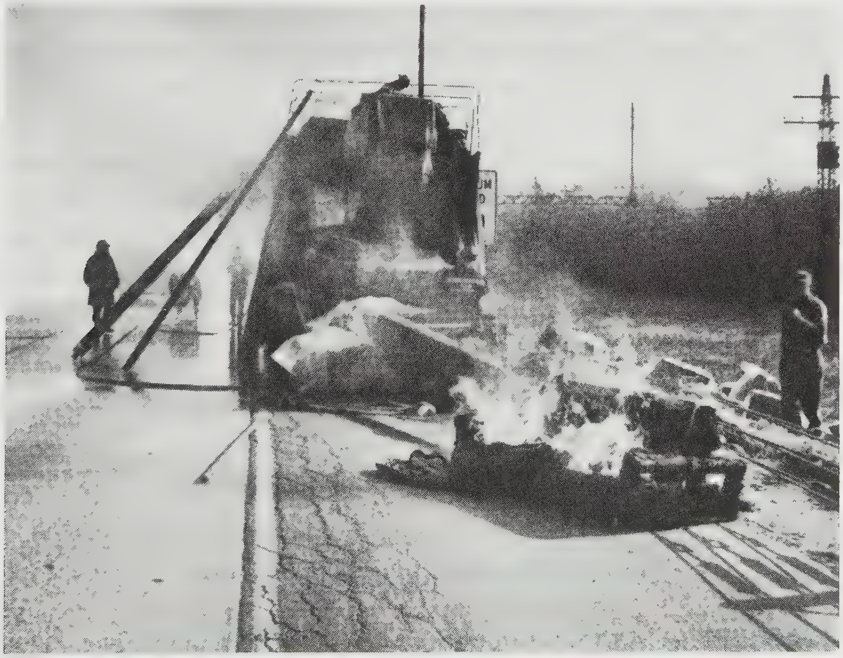


Figure 16.29. Varied cargoes carried by trucks can include explosive and corrosive materials. This truck carried furniture on a Connecticut turnpike, but its cargo might also have included materials that are dangerous.

Although good firefighting practice calls for moving the nozzle into a building as soon as possible, it may be safer at first to attack a truck cargo fire from a distance dictated by the maximum range of a straight stream. You can then approach it cautiously with fog for protection until it is found to be harmless.

Great care should be exercised in overhauling mixed cargoes to prevent a mixture of materials that could become dangerous when in contact with each other. This mischance could happen when containers have been burned or melted, or when cardboard containers have become wet and soggy. The cargo manifest should be examined as soon as possible to discover what the cargo consists of. If the driver has been incapacitated, look for the manifest on his person or in the cab of his truck.

In vehicle fires it is wise to stay clear of a tire that may rupture from heating. Large truck tires can explode violently enough to cause serious injury or death.

When a burning truck is stopped on a slope, its wheels should be chocked to prevent it from rolling if its brakes fail, as happened with a gasoline truck on a bridge in New York City. The burning truck rolled downgrade until it was stopped by the bridge railing.

If a vehicle fire is the result of a high-impact collision, a search of the area for victims should be made, with particular attention under all involved vehicles. There have been cases of people thrown out of their own cars who were found under other vehicles.

In some models of cars, the drive shaft may explode when heated sufficiently, and bumpers can explode and fly through the air for some distance. If a car is well involved with fire, the firefighter's approach should avoid front and rear to stay out of the path of the bumpers; the drive shaft explosion could be dangerous if the car is on its side, with the drive shaft exposed. These risks require a cautious advance which includes starting the water attack at a distance from which the car can be thoroughly cooled before being closely approached.

RAPID TRANSIT FIRES

Rapid transit systems are increasing in number as a means of reducing the heavy vehicular traffic clogging the highways in metropolitan areas. The problems and challenges that these systems bring to fire officers are not new. Elevated railroads have been around for more than 100 years. The first subway was built in New York City in 1904. In the years since then, the frequency of wrecks has been low, but their seriousness has been great. The frequency of fires along the elevated tracks is high, but the damage, with few exceptions, has been trifling. Fire frequency in the subways is slight, but there have been several serious fires. The heat and damage from a fire involving a steel subway car are almost unbelievably great.

Special Problems at Subway Fires

The problems at a subway fire can be numerous. In addition to intense heat, they may include:

- *High life hazard:* One train may contain hundreds of people.
- *Smoke:* Dense smoke and the confinement of a tunnel combine to present a serious life hazard to passengers, train crews, and firefighters.
- *Darkness:* The tunnel is dark and, when the power is cut off, the train will go dark except for small emergency lights.
- *High voltage:* When the current is on, the third rail presents an extreme life hazard. Touching it when grounded is almost always fatal. Hose lines should be kept away from contact with the third rail at all times, even when it is known that the current is off; it could come on again prematurely, without warning. When you apply water, take care to avoid striking the third rail with the stream when the power is on, except from a safe distance. Although the danger of electrocution in this fashion is not great unless the nozzle is held fairly close to the energized rail, there is no sense in taking unnecessary risks. When firefighters are guiding passengers along the tunnel, they should keep passengers and themselves away from the third rail.
- *Access:* Reaching the fire is seldom easy and sometimes can be extremely difficult. Hose lines must be stretched by hand and lines can be very long unless the subway is equipped with an adequate standpipe. Finding the standpipe outlet, however, may be difficult in heavy smoke. If the fire is a long way from the entrance (as has happened a few times in New York City, San Francisco, and Boston when trains ignited far into tunnels under water), the duration of air supplies for self-contained breathing apparatus becomes a prime consideration. Firefighters could conceivably take 20 minutes to reach the fire from the nearest entrance. If it is known or suspected that the duration of the breathing air may be insufficient in the units available, they should be used only when necessary. Using the air sparingly and with great caution may enable the wearer to reach the fire with enough air for his return. Carrying spare cylinders of air, although a burden, may prove worthwhile.

Solutions to the above problems call for several steps to be taken. Power may have to be shut off; this step should not be taken unless necessary, because it will directly or indirectly affect every train in the system and may result in trains being stalled between stations. When this situation happens, passengers become panicky after a short while. Some faint; others get hysterical. If the fire doesn't involve a train, it might be well to hold up the firefighting, or at least shutting off the power, until the trains can reach stations.

The next consideration is the safety of passengers. One handicap is that a rapid transit train usually operates with a crew of only two: a motorman and a conductor, even though the train may consist of several cars packed with people. Therefore, the crew cannot maintain visual contact with most of the passengers; however, the public address system may be operational from the conductor's post, and he could use it to direct or calm the passengers. When the fire officer arrives, he might also use it. When passengers leave the train, they will probably have to be guided to the nearest exit. The firefighters guiding them will have to keep them well herded and provide illumination. The safety of firefighters working in a subway requires that red lanterns be placed on the tracks at least 500 feet on both sides of the point of operation to stop any approaching trains.

Sufficient hose will have to be carried to reach the fire. Pre-fire planning surveys should include tests of radios to determine in-tunnel range and reliability. If it is deficient, other means of nozzle-to-pumper communications should be worked out. (Telephones may be present in the subway.) Long stretches preclude the use of 1½-inch hose; therefore sufficient personnel must be available to stretch a 2½-inch line.

There is little natural ventilation in a subway, but there may be some means of artificial ventilation. Firefighters should be familiar with this artificial system—how it works and how to put it into operation.

Pre-Fire Planning

There are few places where pre-fire planning and familiarization are more desirable than in subways. Fire officers should learn the location of emergency exits, the procedure for shutting off power, and the location of standpipes, if present. The speed of the trains and their braking distances should be learned and considered. For instance, a New York subway train traveling at 35 mph will take 500 feet to stop on service application of its brakes. If motors are reversed and an emergency brake applied, it will stop in about 375 feet. The effect of curves on the unobstructed viewing distance of the motorman should be considered. The proper stop signal is a red light, but, in its absence, any light waved violently is a signal to stop.

Nevertheless, when working on the tracks, officers should keep alert for the sound as well as the sight of approaching trains from both directions so the firefighters can be warned. An escape should be planned in advance because the quarters are cramped and the trains are fast. Whenever firefighters are walking the track, they should keep an eye on safety shelters and walk on the track where the trains would come toward them, rather than from the rear. They should avoid descending to or crossing tracks until sure that there is no train approaching. If there is a footwalk, it should be used in preference to the tracks.

When firefighters cut off the power in a third rail by pulling an emergency switch, they should notify the subway trainmaster as soon as possible. Power in a single car can be cut off by driving a wood paddle between each of the car's contact shoes and the third rail.

Fires on elevated lines do not present all the problems of the underground fires, but they do have other features to be considered. "El" fires frequently involve the wood cross-ties, especially in summer. In fact, I was captain of a company which averaged about six such fires a week during the summer months. In most cases these fires can be extinguished by a hose line located in the street below, but a ladder should be raised (unless the fire is at a station) and a close look taken to ascertain that the fire has been completely extinguished. Take care that the ladder does not protrude into the path of the train; I know of a case where a train hit a ladder, but fortunately no one was hurt. Sometimes it is necessary to take a booster or 1½-inch line up the ladder to complete extinguishment. With this type of fire, it isn't necessary to stop the trains, but it is advisable to keep alert to their coming and to flag them down to slow speed.

Station fires are another problem. Some of the worst fires in New York City have involved subway, surface, or elevated stations. One of the latter extended to buildings on both sides of the street. A surface station fire on the Staten Island Rapid Transit spread with such speed that it killed an off-duty fire dispatcher who was trying to send in the alarm and became the biggest fire in the history of that borough. Two fires in the Times Square station subway complex were extremely difficult to extinguish and one proved fatal. Another station fire led to collapse of a portion of the street above.

In subway station fires, the selection of the entrance for attack is extremely important. The situation should be studied before commitments are made. The same principles that apply to a cellar fire in a large building can be applied, but there is the additional problem of passenger evacuation. Where buildings have basement entrances to the subway, these exposures demand primary consideration and can also provide a good attack base, especially if equipped with standpipes.

FREIGHT TRAIN FIRES

Although a fire department may have a good knowledge of local target hazards and excellent pre-fire plans for coping with them, some of their most dangerous hazards, freight trains, pass through town almost unnoticed. Freight trains may contain a variety of extremely dangerous materials and can also present complicated tactical problems. The very size of a freight train is awe-inspiring; trains more than a mile long are not uncommon. Such a train contains more than a hundred cars, each capable of holding several tons of material. It is not just the size of the train, however, but rather the nature of its freight that is the primary concern in firefighting.

The record of recent freight train fires is not reassuring. Although several have occurred in sparsely populated rural areas, one took place in Houston, Texas, that killed one firefighter and injured 25 more, as well as several newsmen and spectators. The fact that the death-dealing explosion took place 40 minutes after the arrival of a large, well-equipped, and well-trained fire department emphatically illustrates the seriousness of the problems that can be encountered.

The Houston incident happened on October 19, 1971, when a

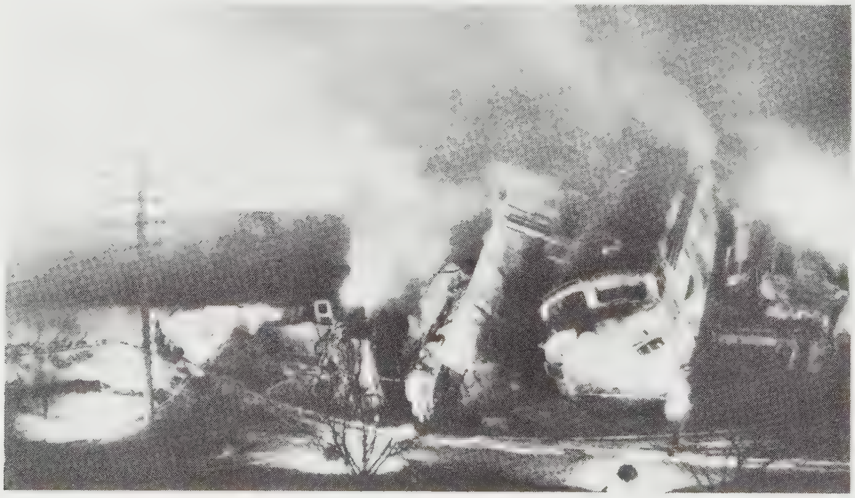


Figure 16.30. *Collision or derailment of freight trains often causes fires that are difficult if not impossible to fight and extremely hazardous to civilians and firefighters. Tank cars carry the most dangerous cargoes.*

freight train derailed, resulting in a 16-car pile-up that included 12 tank cars. Six of these tank cars carried vinyl chloride, three fuel oil, and one each acetone, butadiene, and formaldehyde. Vinyl chloride escaping from a damaged 48,000-gallon tank car ignited immediately. Forty-five minutes later, a second carload of vinyl chloride, which had been heated by the initial fire, exploded violently. Onlookers estimated that there was a fireball about 1,000 feet in diameter. Large sections of the tank car were later found as far as 400 feet from the derailment site.

This incident was quite similar to one that happened at Crescent City, Illinois, on June 21, 1970. There, a 15-car derailment caused a release of propane from one of nine cars containing this gas. Ignition occurred immediately, and during the following 4½ hours, several explosions took place that injured 66 firemen and bystanders. Large portions of tank cars were found as far as 1,700 feet from the site.

Investigations by the National Transportation Safety Board of several such fires led to the issuance of the following statement by the board's chairman: "The reduction in property damage achieved by fire suppression methods in past accidents has been generally insufficient compared to the risk assumed [by the firefighters] of injury and death when acting with inadequate or improper information as to the contents of the cars."

It appears that the most dangerous situations occur in those wrecks in which several tank cars end up lying close together in the wreckage and in which a fire breaks out and heats a tank car or cars containing hazardous materials. In this sort of situation, the board recommends that the risks should be studied and the materials identified before firefighting methods are decided upon. If it seems that the firefighting resources will be unable to cope with the fire problem, or if there is insufficient information on the nature of products exposed to the fire, "a prudent course of action may be complete evacuation of the area within a radius of 2,000 feet," according to the board. Even when firefighting is attempted, there is no reason to allow spectators within the danger zone.

A chart prepared by the board gives some pertinent facts on recent railway fires. It is apparent that vinyl chloride and liquefied petroleum gases have been the biggest and most frequent hazards. It also shows that explosions are not always immediate, and indicates the reasoning behind the recommendation for a 2,000-foot clearance.

Railroad shipments do not have a weight limit on hazardous materials, and the placarding is different from that of highway carriers. The New York State Division of Fire Safety has issued some valuable information to help determine the risk in transportation

Date of Accident	Location	Number of Cars in General Derailment	Number of Tank Cars Derailed	Time Between Initial Derailment and Subsequent Explosions	Contents of Tank Cars	No. of Fatalities	No. of Injuries	Types of Casualties	Distances Portions of Tank Cars "Rocketed"
Jan. 1, 1968	Dunreith, Indiana	14	6	45 Minutes	Acetone, cyanohydrin, methyl methacrylate vinyl chloride, ethylene oxide	0	5	Firemen and police	700 feet
Jan. 25, 1969	Laurel, Mississippi	15	15	Immediate	Liquefied petroleum gas	3	32	Residents	1,600 feet
Feb. 18, 1969	Crete, Nebraska	31	3	Immediate*	Anhydrous ammonia	9	53	Residents	200 feet
Sept. 11, 1969	Glendora, Mississippi	15	10	5½ hours and 16 hours	Vinyl chloride and fuel additive	0	1	Power company serviceman	850 feet
June 21, 1970	Crescent City, Illinois	15	9	1 hour to 4½ hours	Propane	0	66	Firemen, reporters, photographers	1,700 feet
Oct. 19, 1971	Houston, Texas	16	12	45 Minutes	Vinyl chloride, fuel oil, acetone, butadiene, formaldehyde	1	37	Firemen, reporters, photographers, spectators	400 feet

*No fire, Brittle fracture of tank car in crash allowed Instantaneous release of entire cargo of ammonia, producing poisoning. However, similar hazard in fire exists.

Figure 16.31. *Synopsis of railroad tank car hazardous material accidents investigated by the National Transportation Safety Board.*

incidents. The following is adopted from a report by the division's senior chemist, J.D. Green.[3]

> The marking of railroad box and tank cars is quite different from that required for motor carriers. Also the weight requirements are entirely different. Railroad shipments do not have a weight limit on hazardous materials. Placarding requirements are based upon the material and the type of packaging. For example: If a box car carries 1 gallon of a flammable paint thinner, the car must be placarded DANGEROUS.
>
> If the unit package is a 1-quart metal can or a 1-pint container, the box car may be full without any placard whatsoever. A box car could be filled with explosives, Class B, and would display the same dangerous placard as a 1-gallon can of flammable liquid or a 5-pound can of oxidizer, etc. A box car load of chlorine cylinders (Type 3A) would not be placarded at all. Obviously, the degree of risk cannot be determined from

the placard. Generally, it is necessary to examine the shipping papers to determine the following:

1. Is a hazard involved?
2. What is the degree of hazard?
3. What quantities of dangerous articles are present?

According to federal regulations, "the driver of each vehicle," and "the conductor of each train" shall have the shipping papers in his possession. The following information is required on these papers:

1. Name of the commodity (proper shipping name)
2. Classification of commodity
3. Weight or volume of commodity

Explosives, radioactive materials, and poison gas placards indicate that a hazard exists. But the degree of hazard and quantities involved cannot be determined from these placards alone.

Commodity Classification	*Railroad Placard*	*Truck Placard*
Explosives, Class A	EXPLOSIVES	EXPLOSIVES A
Explosives, Class B	DANGEROUS	EXPLOSIVES B
Explosives, Class C	None	None
Flammable liquids	DANGEROUS	FLAMMABLE
Flammable solids	DANGEROUS	FLAMMABLE
Oxidizing materials	DANGEROUS	OXIDIZERS
Corrosive liquids	DANGEROUS	CORROSIVE
Compressed nonflammable gases in containers other than cargo tanks on trailers	None	COMPRESSED GAS
Compressed nonflammable gases in cargo tanks on trailers	DANGEROUS	COMPRESSED GAS
Compressed flammable gases	DANGEROUS	FLAMMABLE GAS
Poisonous liquids or gases Class A	POISON GAS	POISON
Poisonous liquids or solids Class B	DANGEROUS	POISON
Tear gases, Class C	None	None
Radioactive materials	DANGEROUS RADIOACTIVE MATERIAL	RADIOACTIVE

One of the complicating factors at a fire in a railroad yard is the difficulty of getting hose lines to the fire. Usually hydrants are not conveniently located, and apparatus cannot be driven close to the fire. Thus, long hose stretches must be made by hand. Another complication is that if hose lines are laid across tracks, precautions must be taken to ensure that the trains are not driven over them. In a yard with many tracks, this care can be a problem, especially at night. Pumpers will frequently be located at distances from the fire which may require high pump pressures that may cause hose to burst. In some cases, water relays may be necessary.

All in all, freight train fires place a fire chief in an unenviable position. He can suddenly be confronted with a fire involving substances over which he has had no fire prevention authority or advance information. Some of these fires may involve materials which are dangerous from one or more standpoints: they can be explosive, corrosive, or highly toxic. Almost any long freight train carries a mixture of fire hazards which no fire prevention code would permit to exist in buildings. Admittedly, it is very difficult to predict just what may happen and what products may become involved in a freight yard fire, but such tactical problems as hydrant locations and hose lays can be considered in pre-fire planning. Arrangements can be made in advance with railroad officials to assure that firefighting operations can proceed without interruption and that the impairment of rail service will be held to a minimum.

SHIP FIRES

When the size of a ship is compared to a building, it is plain that in most cases it would take a large building to equal even a modest-sized vessel. Many ships are well over a block long and equal in height to a five-story building. The fire problem is further complicated by limited access; there are not nearly as many ways of getting water on the fire as there would be in the average building. Another complication is that the fire may have to be approached from the top, a situation which is similar to attacking a cellar fire by starting down from the roof of a five-story building (Figure 16.32).

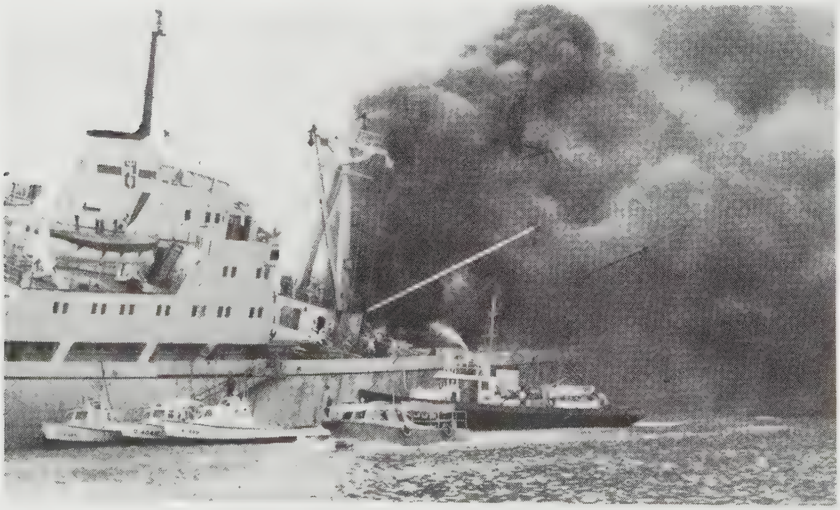


Figure 16.32. *At ship fires, the fire may have to be approached from the top, which is similar to attacking a cellar fire by starting down from the roof of a five-story building. The ship shown is already listing from the water being poured into its hold.*

Ship fires are usually of four types: engine room, cargo hold, living area, and paint locker. Each calls for a different method of attack.

The engine room fire may involve a quantity of fuel oil which will create considerable heat and dense black smoke. Fog streams will be beneficial to protect against the heat, and also because fog can extinguish a fuel oil fire. Lloyd Layman reports a test fire on a ship at Fort McHenry, Maryland, in which fog applied through the engine room skylight extinguished a fuel oil fire at the bottom of the engine room far below.

Of course, self-contained breathing apparatus is highly desirable in an engine room fire. Ventilation can be effected by removing skylights up on deck and through engine room ventilators. Sometimes foam may have to be applied to extinguish a fuel oil fire. There have been cases where this was done successfully from up on deck.

Fire in a cargo hold should be treated differently. The fire may be deep-seated in a combustible dry cargo. Usually hold fires do not burn rapidly, and as a consequence they generate a large quantity of smoke. Sometimes a stubborn pocket of fire persists even after the smothering system, which most ships have installed in cargo holds, has been used by the ship's crew. It is well for a fire chief to take time for a discussion with the ship's cargo officer to find out just what is in the hold and what would be the best steps to take. Meanwhile hose lines should be stretched on deck and made ready for use. If the chief determines that the cargo is not dangerous and that the fire can be safely extinguished with water, then such an attack can be mounted.

Ventilation can be accomplished by removing hatch covers and trimming ventilators (turning them away from the wind). Ladders can be lowered into the hold for access but should be well secured. Firefighters can be lowered by ropes. Perhaps entry can be made through a cargo port or bulkhead door. It should be remembered that cargo holds usually have an intermediate or "tween deck" which also has a hatch that may or may not be covered at the time of the fire. If the ship's officers aren't sure, stevedores, if present, should know.

Continuous examination should be made for hot spots on the other sides of the bulkheads fore and aft of the fire. Steel bulkheads are good conductors of heat; therefore combustible material should be removed from contact with the bulkhead. At the same time, watertight doors which, if open, may allow water to escape from the hold on fire, should be closed tight to prevent water damage to other parts of the ship.

Severe cargo hold fires may require heavy streams or large-capacity distributor nozzles. Sometimes a successful attack may be had by cutting with a torch through a bulkhead and applying a hose stream through the opening.

Some extinguishing success has been reported by using large quantities of carbon dioxide to fill a cargo hold that is involved with fire. In this operation, the hold is filled and then sealed for a day or two. When the chief feels that the fire is extinguished, he opens the hold for inspection; charged lines should be on hand when this is done. Sometimes, in order to save the ship, it may be necessary to flood the hold with water. This procedure should be done with the advice of the ship's master and other maritime experts so that the vessel will not capsize. Sometimes the ship can be towed to a location where the water is just deep enough for it to settle evenly on the bottom with the decks awash. The place selected should not have a rocky or uneven bottom and should not be in a channel or other location where the beached ship would interfere with navigation.

Fire in a ship's living quarters will feed on fuel sources similar to those in residential structures and will react similarly. Firefighting practices, therefore, should be the same.

Fire in a paint locker or similar ship's stores locker can be quite difficult to extinguish. Such lockers are usually the size of a living room and are located where both access and ventilation are difficult to achieve. They contain much flammable material; therefore, high temperatures and dense smoke will be present. There have been times when the heat from such a fire warped the steel deck above. Sometimes such fires have been extinguished from a hole cut in the deck above. Explosion is a possibility at such a fire due to the presence of flammable liquids.

At any ship fire it should be remembered that the water used will not run off as at a structural fire ashore; it will accumulate below decks. The water may settle unevenly and tip the ship over. This motion does not happen suddenly, and it is noticeable long before the center of gravity moves to a dangerous point. If there is any doubt, readings can be taken on the inclinometer in the wheelhouse. If it can't be reached, a sighting from a remote point that compares the angle of list with a stationary object will show if there is a change. I watched the sinking of the *Normandie* and the only way a change could be noted was by such a sighting.

Fires on oil tankers are fought with the same methods used for such fires on land; however, large quantities of oil may burn on the surface of the water and threaten nearby ships and piers. Hose streams and boat streams can be used to drive the burning oil away from vulnerable places.

Barge and scow fires may have to be fought from two sides, although, if moored, these vessels may be boarded with hose lines. If the tide or current might carry the burning barge to where it could no longer be reached or where it might extend fire to other property, hose streams should be used to keep its hawsers from burning through.

PIER FIRES

In this context a pier, quay, or wharf all have the same general meaning, i.e., a structure erected on shore for the loading and unloading of ships. A dock or slip is the space in the water between piers which project outward from shore.

There are several types of pier construction. Some piers are built upon solid fill, others are built upon piles, and some rest on other kinds of supports such as arches carried by blocks of stone. Pier superstructures also vary; some piers are uncovered, some are covered with a single deck, and some are double-deck, or two-storied.

A characteristic of most piers is that the superstructure presents a large undivided area through which fire can travel rapidly. The rapidity with which fire can flash over a long pier was clearly illustrated to an engine company where I worked as a lieutenant. They took the hose wagon down the pier (a two-deck enclosed pier) to where the fire was located. By the time they turned the wagon around and started driving back to the land end, the fire flashed over and overtook the vehicle, which had to be abandoned by the firefighters, who took refuge on a stringpiece until rescued by a fireboat. There have been cases where the fire traveled so fast firefighters had to jump overboard. Although some piers have draft curtains, there is usually considerable air movement on a pier and therefore a good oxygen supply for a fire.

Usually a large pier contains considerable amounts of combustible cargo, some of which is in combustible containers. It is common for cargo trucks to be on a pier along with many forklift trucks, all containing engine fuel (Figure 16.33).

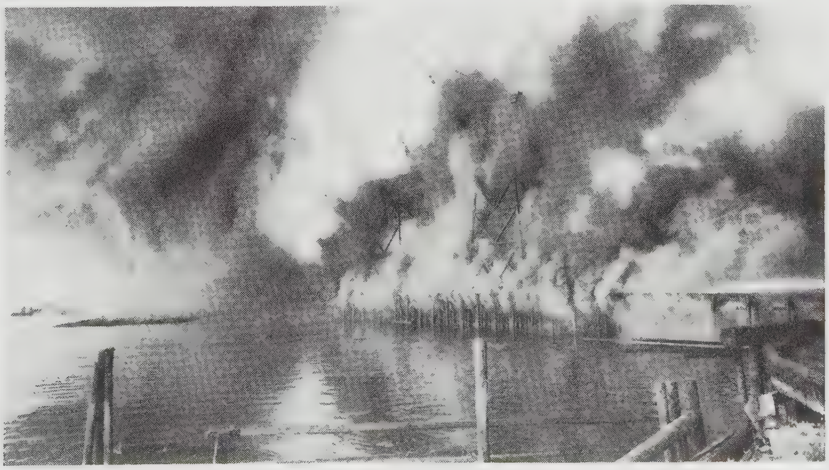


Figure 16.33. A pier, because of its size, limited access, and great quantities of combustible material stored on it, presents a difficult problem when afire. The under-pier fire shown is a type particularly difficult to extinguish.

Under-pier or substructure fires are difficult to reach. Some cities require access holes in the deck for the insertion of cellar nozzles, but they are frequently covered with cargo. If the water level is low enough and access can be had from a small boat, a hand line can be operated from the boat. Some cases have been reported of the successful use of nozzles on floats operated by scuba divers.

It is at large pier fires that fireboats prove their worth. Not only do they have access not available to land companies, but their heavy-caliber streams are necessary to extinguish a huge body of fire when a pier is heavily involved. The limited usefulness of land companies can be understood by estimating the length of time it would take them to stretch hose lines down a 1,000-foot-long pier. Calculating how long it would take them to reach the ideal rate of flow for a structure enclosing 3 million cubic feet is further evidence of their inability to cope with large pier fires.

Some piers have roof monitors, a sort of superstructure with windows which sits on the roof peak. A heavy fireboat stream can sweep these windows out and thus ventilate the roof. Closed cargo doors will obstruct fireboat streams unless they are opened by firefighters on the stringpiece or are dislodged by fireboat streams.

The presence of ships tied up to the pier complicates matters by obstructing the fireboats and also by presenting highly valuable and serious exposures. Sometimes a fireboat will have to tow a ship out of the way, but if private tugs or U.S. Coast Guard vessels are at hand, they can do the towing while the fireboat attacks the fire.

The fire department should make every effort to keep informed of the presence of dangerous cargoes on a pier. In 1957, a fire on a large pier in Brooklyn extended to a cargo of 30,000 pounds of explosive material. The ensuing blast killed ten spectators on neighboring piers. No fireman was killed, although the crew of one fireboat was knocked overboard by the blast. Most of the victims were hit by steel fragments, but one man whom I helped to extricate was killed when a heavy steel door was dislodged and fell on him.

RURAL FIRES

Water supply is important at almost every fire, but it is of the greatest concern in rural areas where it must be trucked to the scene or obtained from a nearby natural source. Firefighters, like most humans, are creatures of habit. They tend to do what they are used to doing. If they usually truck water to fight a rural fire, they will probably do so even when an adequate natural source is close at hand and usable. I witnessed a case where four fire departments were shuttling water by trucks from hydrants in town to a rural fire two miles away. There was, however, within 150 feet of the fire a creek of ample size and depth for drafting and with two places where pumpers could easily draft—but nobody thought of using it, because this procedure was not their routine practice.

Natural water sources are surprisingly numerous and convenient when looked for (Figure 16.34). Swimming pools, lakes, fountains, rivers, creeks, streams, and bays can provide water for firefighting where hydrants are not available. Transported water, although limited in amounts, can be just as effective as a city system—when the amount is sufficient. A fire department water tank truck in the farmer's front yard is as good as a hydrant if it carries enough water for the fire encountered, or if the supply can be maintained by a tanker shuttle (Figure 16.35).

In cases where the water transported on the initial response is not sufficient, a tanker shuttle, utilizing a portable holding tank of canvas or plastic, enables the tanker to dump its contents and go to the nearest water source for a refill. A pumper at the fire scene can draft out of the portable tank while the tank truck is gone.

The limitations of this procedure are:

1. The capacity of the tank truck
2. The capacity of the portable tank
3. The distance to the water source
4. The time for the tank truck to discharge its contents
5. The time for the tank truck to refill

Tests have shown that most tank trucks are slow to discharge. When the method of discharge is gravity, the head is low to begin with and diminishes rapidly as the water exits; therefore the last few hundred gallons move out slowly even when the discharge port is large. Even a five-inch outlet will not move water rapidly when the head is down to one foot or less.

When the method of discharge is by pumping, the limiting factor is the diameter of the pipe between the tank and the pump. A 1½-inch pipe will limit the discharge to less than 150 gpm. A three-inch pipe will give a flow somewhat over 300 gpm, which means about three minutes to discharge 1,000 gallons of water.

The refill rate of a tanker being fed by a portable pump at a natural source is usually on the order of 200 to 300 gpm, depending upon the pump and lift. It should be noted well that the volume of pump discharge diminishes as the height above the pump increases. A 300-gpm pump will not furnish that amount when pumping uphill.

If optimum conditions are present, a picture like the following should result:

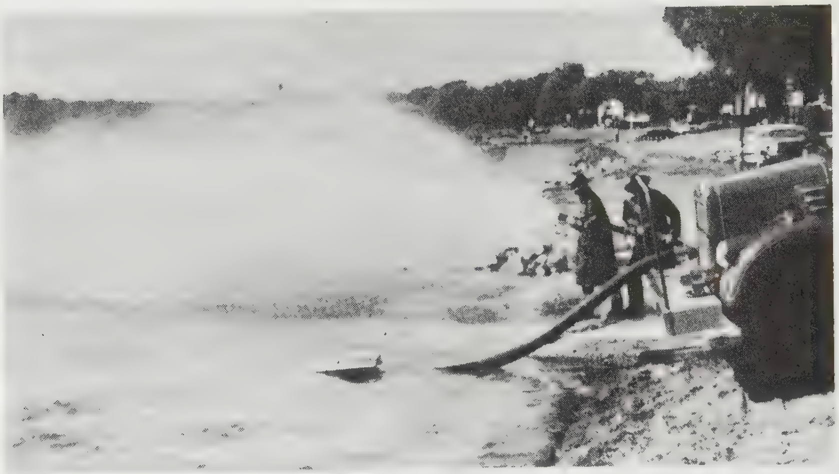


Figure 16.34. Lakes and ponds are often used as a water source in rural firefighting. In this drill, a floating suction device is used to keep the strainer off the bottom of the lake. The fog nozzle used, by the way, was made in 1863.

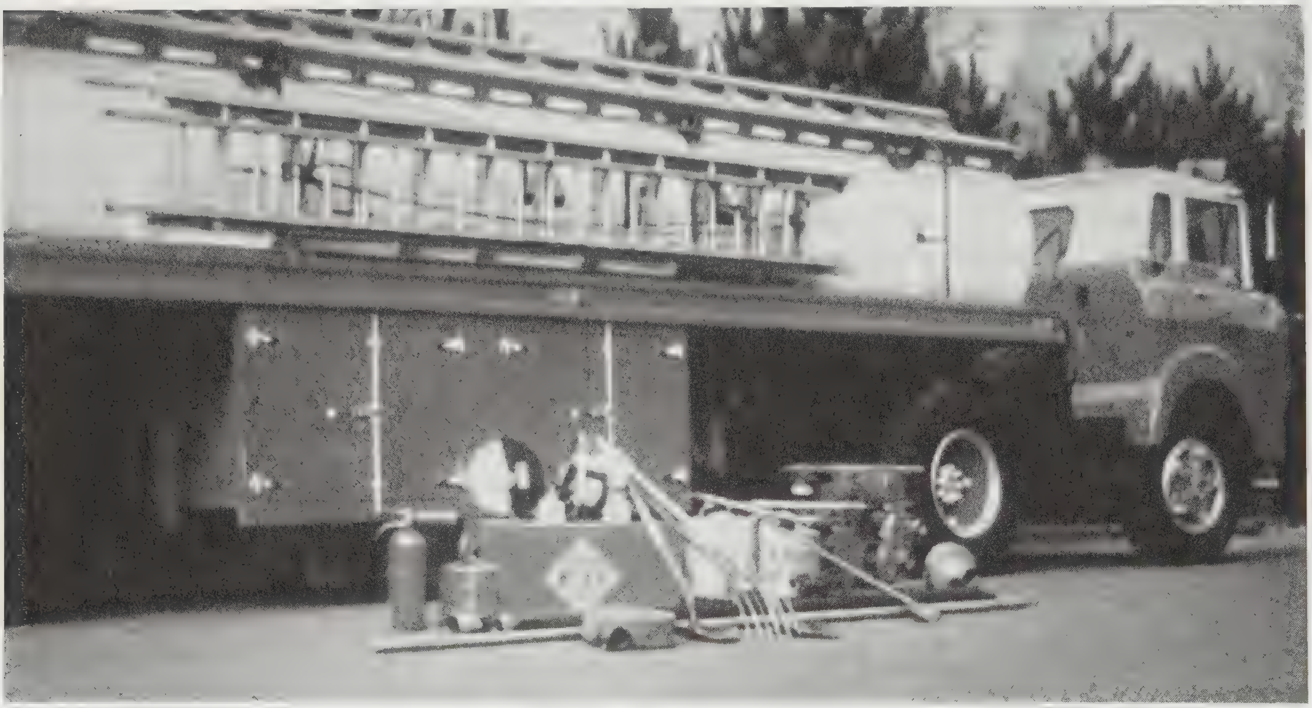


Figure 16.35. Some rural fire departments use water tankers with ten-inch dump valves that can drop 1,500 gallons into a portable holding tank in one minute. Others use a pump-assisted discharge which gives a like amount. A report of an actual fire in Wisconsin states that a tanker shuttle supplied 3,375 gpm for two hours; this shuttle involved 15 tankers supplying six pumpers. Each tanker was able to dump its 1,800-gallon load through a ten-inch dump valve into a 2,100-gallon holding tank in 75 seconds. The water source was one mile from the fire, and the reported average run was eight minutes per tanker, including dump, drive to the fill site, fill, and return to the fire. This speed gave an average discharge rate of 225 gpm per tanker. The tanker shown is equipped to carry ladders and rescue tools as well as water.

1. Discharge rate from tanker, 300 gpm
2. Refill rate for tanker, 300 gpm
3. Travel time for tanker for a two-mile round trip, three minutes
4. Turn-around time (both ends totaled), one minute

Thus it can be seen that, theoretically, one tank truck of 1,200-gallon capacity could maintain a flow rate of 100 gpm. In actual practice this rate would be unlikely, and a more accurate figure would be about 75 gpm under good conditions.

Some of the limitations are design faults which could be improved upon. For instance, tank vent openings are sometimes so small as seriously to increase discharge and refill times. An adequate vent at the top of the tank is needed for the escape of air during refill and its admission during discharge.

In groups of tests in Iowa and Wisconsin, it appeared that the average discharge rate of tankers randomly selected was on the order of 50 gpm under good conditions for a run of a mile each way (for a round trip from the fire to the source of water). Thus, with each tanker in a shuttle delivering an average of 50 gpm, multiplication will quickly show how much water can be discharged by using more than one tanker. Conversely, division can show how many tankers are needed to provide the required flow.

This knowledge is useful in deciding whether to use a tanker shuttle or a water relay. Five tankers can reasonably provide 250 gpm when shuttling from a source one mile distant from a fire. An equivalent amount delivered though a single line of 2½-inch hose would require at least four pumpers and nearly 5,800 feet of hose.

With the relay, there is danger of burst hose. With the shuttle, a truck may become disabled. The latter would have less serious consequences than the former, because flow would be reduced but not altogether stopped.

There is a point where the shuttle becomes more efficient than the relay. At lesser distances, pumpers can supply the necessary pressure and enough hose by relaying the water, but at greater distances the shuttle would usually be more efficient if the tankers are available. Much higher discharge rates than those given above can be obtained with fast-dumping tankers or large-diameter hose. See the examples in Figures 16.35 and 16.36.

Careful Use of Water

From the practical standpoint of available apparatus, rural firefighters cannot often develop a large flow rate of water. On the other hand, water requirements are not usually large. Normally, rural fires are one-family dwellings or barns. A well-involved dwelling can be

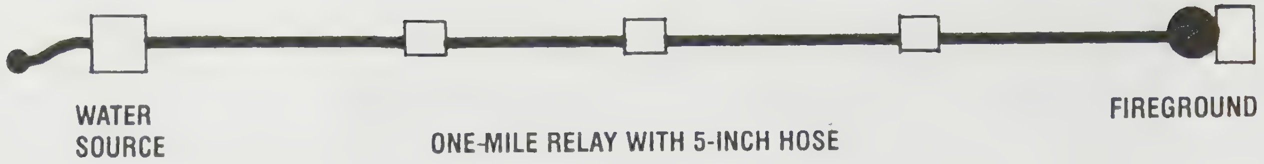


Figure 16.36. The delivery rate of 225 gpm per tanker invites comparison to a relay through large-diameter hose. If five tankers can deliver 1,125 gpm for a one-mile run, what will the alternative do? On a level stretch, such a relay would require about 5,800 feet of hose because hose does not lay perfectly straight. Theoretically, four pumpers of adequate capacity, placed properly, could deliver 1,125 gpm through 5,800 feet of five-inch hose to an attack pumper or holding tank. Ten pumpers could do it through four-inch hose. The limiting factor is the amount of hose available. Other influencing factors include time required, consequences if hose bursts, and terrain. Some fire chiefs regard large-diameter hose as essential for large-scale disasters such as earthquakes. Chief Charles Rule calls it a "temporary above-ground water main."

extinguished with 500 gallons of water or less. A barn presents a different problem, but not always an insurmountable one if approached properly. The ideal rate of flow applied to the dwelling would probably indicate a rate of 120 gpm or less. The barn, if of average size, would require a much greater flow. For instance, a barn 30 × 60 × 30 feet would need about 400 gpm. Therefore, the flow for the house would not be adequate for the barn. The flow for the barn, however, is still within the range of a 500-gpm pumper, provided that there are sufficient hose lines and nozzles available to apply the water at the rate needed.

The amount of water available will not extinguish the fire unless it is applied at a sufficient rate. If 1,200 gallons are applied to the barn at 100 gpm, the expected result would be total destruction. But if the 1,200 gallons are applied at 450 gpm for two minutes and the remainder at a lower rate for mop-up, the results could be quite satisfactory. Some rural fire chiefs insist upon spreading the available water out in time so it will not be used up before the fire is out. Often the result of such a policy is total destruction of the involved property, with water left in the tank.

The "Blitz Attack"

More modern thinking is that a hard-hitting, high-volume attack—called the "blitz attack"—will knock down the main body of the fire quickly. Some rural departments are now using large tankers with ten-inch dump valves that can drop 1,500 gallons into a portable holding tank in one minute. This attack is usually provided by one 3-inch or two 2½-inch lines discharging 500 gpm. This rate of application will not always be necessary, but the capability to supply it should be provided, just in case. A 30-second application at the ideal rate of flow and a follow-up at about one-fifth that rate could accomplish extinguishment in a total of five minutes with less than 1,000 gallons.

Rural firefighting is often devoted almost entirely to the protection of exposures. In many cases, the property protected was never severely exposed, but its protection gave the fire department an opportunity to appear useful, without coming to grips with the main fire. The basketball axiom that a good offense is the best defense can be applied to rural firefighting. Probably, more times than not, an aggressive attack on the fire would be the most efficient means of protecting possible exposures.

The old ideas of water conservation and exposure protection should be replaced by an aggressive, high-volume attack. Of what value is the water left in the truck's tank when the building has burned to the ground? Of what use are 1,000 gallons if applied at a rate below the critical rate, and the fire continues to burn? What good are 20 firefighters if the water is applied at a flow so low that the premises burn down in front of them?

Barns and Silos

One phase of rural firefighting that is seldom found in the city is extinguishing fires in dairy barns and silos. Firemen in dairy areas should be trained how to free and evacuate dairy cows. They also should be aware that whey from a creamery—which the creamery will usually furnish gladly—is a good (although smelly) wetting agent for deep-seated hay or grain fires.

Creameries and dairies will usually have some milk tank trucks available to fill with plain water, as well as whey, and send to a rural fire. Another source of water transportation is the truck-mounted concrete mixer. They usually can hold about 1,100 gallons.

Silo fires are a problem to rural fire departments. Usually they involve the removal of the silage to get at the portion that is burning—a tedious, time-consuming procedure, which will keep volunteers away from their regular work and sleep for an extended period. There have been cases where the application of carbon dioxide, through the subliming of large quantities of "dry ice," has been effective. The chunks of dry ice were placed on top of the silage and, as the carbon dioxide vaporized, the gas permeated the pile.

There also have been cases where the silo was sealed tightly so that the fire was smothered by its own gases. Although carbon dioxide is the gas given off in largest quantity by a fire, carbon monoxide is also given off, and there have been explosions when air was later admitted. Some have killed firefighters.

There have been successful cases of total flooding with water in which the water was applied at the top of the pile and application continued until all the silage had been well soaked. This, of course, calls for huge quantities of water and quite a bit of time at the application rates usually available in farm country.

Safety Precautions

It is not wise to allow anyone to stand on the top of a pile of silage when there has been fire below. There is the danger of falling into a pocket of ash which would give way easily under the weight of a person.

The same kind of accident could happen where hay has been burned in a barn. This accident can be prevented in a barn by placing ladders or planks atop the hay to stand upon. Deep-seated hay fires should be attacked first with piercing nozzles to reach into the fire pocket. Then the hay must be removed from the barn until it is certain no fire remains. Charged hose lines should be ready at all times during hay removal. They may have to attack instantly if fire suddenly flares up when air comes in contact with smoldering hay.

Some rural fire departments have hay probes made of a length of pipe with perforations in one end. The perforated end is pushed deep into the hay pile and a thermometer lowered into the pipe. The temperatures shown help the firefighters to determine the location of the fire or, in other cases, to discover if hay is heating spontaneously to a dangerous degree. Of course, a pyrometer would give a much quicker response than a thermometer and can be read remotely; however, it is far more expensive.

In determining the defensive or offensive action to be taken at a rural fire, certain factors take on added importance. The direction and velocity of the wind are very strong influences on tactics, especially where a ground fire may extend to buildings.

Inasmuch as water supply will probably involve the use of natural sources, they should be identified in a manner that will make them easy to find, so that pumpers may draft from them or water tankers refill from them without undue delay.

Need for Knowledge of Rural Roads

Rural firefighting demands a good knowledge of roads and the use of reliable maps. It is necessary to know the roads for three reasons: to find the fire, to be able to select natural firebreaks for a defensive stand against a woods or brush fire, and to find natural sources of water.

Many rural fire departments not only carry maps, but also have directional cards in the fire station which tell how to get to each rural property. Some designate numbers to each road and property. The property owner is given a metal sign similar to an automobile license tag. The sign, erected on the road in front of the property near the mail box, allows the occupant readily to identify the property when calling the fire department and thus helps the department to find it. Most of the rural numbering systems follow definite codes whereby the number discloses the location and the route to get there.

Wildland-Urban Interface

It is not within the scope of this book to delve deeply into the practices employed in attacking wildlands fires. That subject is a separate study; however, many rural buildings are lost each year from fires that started in natural cover fuel sources, such as grass or brush. In what was one of the most destructive days in the history of the New York City Fire Department, over 100 buildings on Staten Island were destroyed in a series of brush fires. In California, brush fires cause the destruction of many houses with almost annual regularity. Far less dramatic—but maybe even more costly—is the collective loss of individual structures, or two or three buildings at a time, in many communities by grass or brush fires every year.

Early attention should be given to the protection of structures which may be exposed by a wildland fire. Too often, we find that the firefighting forces ignore the possibility of structural loss because it is not immediately apparent. By the time the hazard is recognized, it is too late for effective action.

A size-up of a ground cover fire should give priority to the protection of occupied or otherwise valuable structures which may be—or which may become—endangered. When water is at a premium, which is usually the case in rural fire situations, it may be better to use it for the protection of buildings than for the extinguishment of the burning grass or brush.

Wind direction, natural firebreaks, and the value of exposed property are priority items in evaluating tactical considerations at rural fires. Usually, life hazard is minimal, with the exception of injury to the firefighting force. Communication takes on a different aspect than at city fires because of distance—distance from headquarters and distance from one fire front to another—and also because of the fluidity of the fire fronts.

A further control problem is confining the activities of the firefighting units to the duties assigned. Large rural fires usually attract many autonomous volunteer units who may wish to exercise their own choices in selecting tactical positions. Extensive rural fires require mutual aid that is well planned. Good mutual-aid planning provides for strict discipline in company operations as well as close coordination of all firefighting activity.

FIRES IN HOSPITALS AND NURSING HOMES

The problem of safe evacuation of patients from nursing homes and hospitals is almost insurmountable. When the occupants of a building are unable to escape unassisted, rescue becomes a one-to-one proposition—it takes at least one firefighter to rescue each patient. Therefore, it can be readily seen that a first-alarm firefighting force of 16 individuals should not be expected to rescue more than that number of people. There have been cases where a nursing home fire took place under ideal conditions, i.e., on a Sunday afternoon with many visitors present to help evacuate the patients, or where discovery and alarm were immediate, yet in both situations the death toll was high.

A fire in such an occupancy presents the officer in charge with some serious decisions. Should all efforts be devoted to evacuation, or should an attack be made upon the fire? It would be easy to avoid this question here by saying it will have to be decided according to the particular situation at the fire scene. The purpose of this book is, however, to discover and answer questions, rather than avoid them. In this situation the answer is to attack the fire.

If additional firefighters are available for patient removal, they can be used for that purpose, but quick knockdown of the fire will probably benefit more potential victims than will removal, which is bound to be slow, difficult, and possibly injurious. If a quick knockdown is not possible, confinement is the next best action. While hose streams and judicious ventilation check a fire's advance, patients can be safely removed.

Sometimes, ventilation can alleviate the problem greatly. Smoke ejectors can be placed to keep smoke out of certain areas, and smoke which has already penetrated those areas can be removed by natural and mechanical ventilation. Where built-in air-handling systems are present, they should be shut down if it is found that they are carrying smoke to other areas.

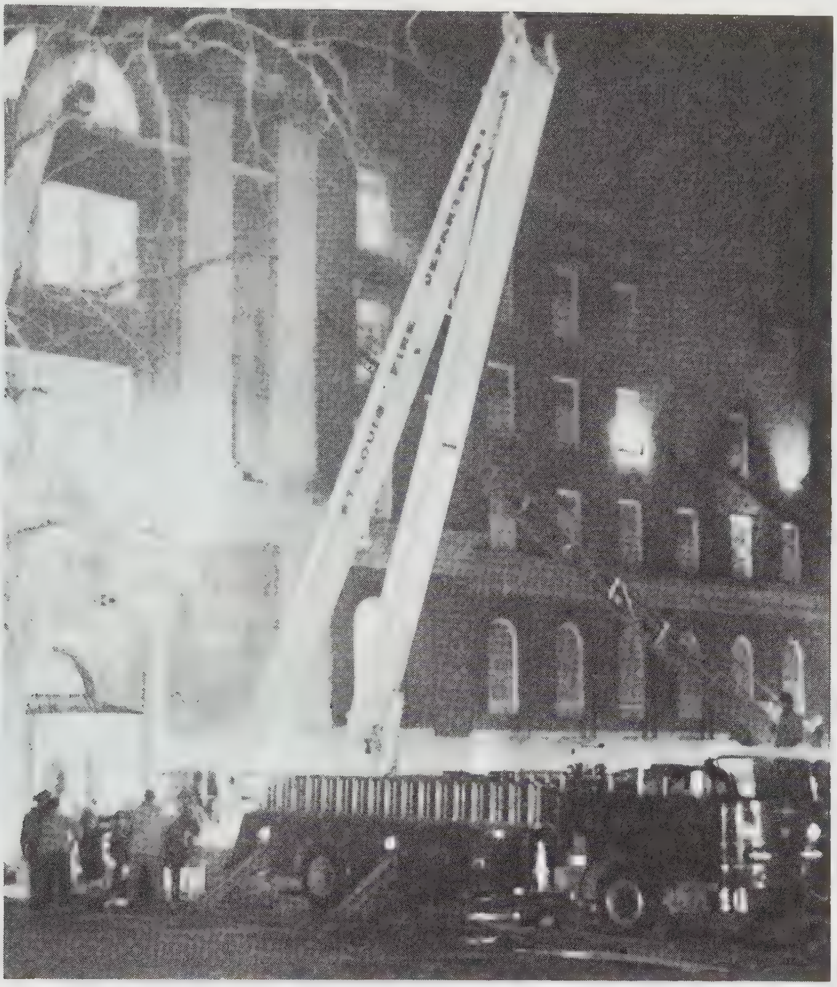


Figure 16.37. *Older hospitals are usually set well back from the street, frequently on an elevated terrace. Elevated platform and aerial ladders shown here are positioned on a lawn, which could pose a stability problem that could be alleviated by placing steel or plywood pads (nine square feet) under the tormentor jacks.*

It should go without saying that hospitals and nursing homes deserve a heavy first-alarm response and that there should be no hesitation in calling additional aid to such a fire if there is any indication that it may be needed.

FIRES IN SHOPPING CENTERS

For many years stores, other than the neighborhood type, were concentrated in a central area in most cities, but the increase in the number of automobiles after World War II led to a substantial change. The shopping public was no longer dependent on trolleys and buses;

they preferred to go to the store in their own cars. Downtown streets lacked sufficient parking spaces, so the suburban shopping center, designed to give ample room for automobile parking, provided the answer. The concomitant exodus from the city to the suburbs furthered the growth of these shopping centers.

Shopping centers now present to the fire service a complexity of problems that did not exist a generation ago. For one thing, they are located on the fringes of cities rather than at the centers. Therefore, water supply and the proximity of fire stations are not as adequate as those downtown. Inasmuch as shopping centers are set back a considerable distance from public streets, there are many cases where hydrants are excessively distant from the buildings to be protected, and other cases where the hydrants near the buildings are on mains that are not large enough to give an adequate water supply.

Although the units in many shopping centers are separated by good fire walls, a great number of centers lack this fire protection (Figure 16.38). Loss records show that many fires involved several stores. In some cases, subdivisions existed but had weaknesses which permitted fire extension. Ceiling spaces and beam ends seem to provide the common channels of fire extension in shopping centers and, consequently, tactics given previously for taxpayer fires are applicable.

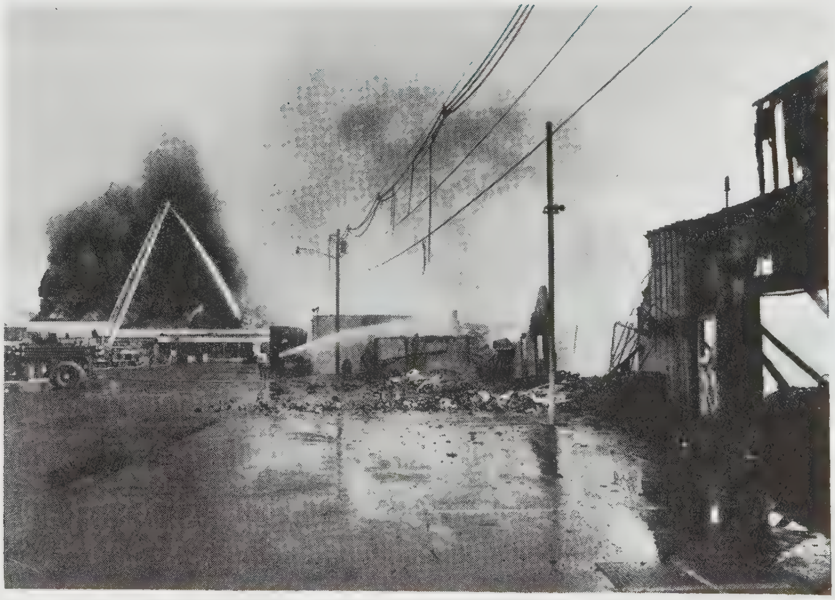


Figure 16.38. *An inadequate number of fire walls permitted fire to travel through this entire shopping center. Ceiling spaces and beam ends contributed to the extension of this fire. Tactics used at taxpayer fires would apply here.*

FIRES IN ENCLOSED MALLS

The enclosed mall type of shopping center presents another problem to the fire service. There, stores are located on each side of a covered center mall. During business hours, all stores have their fronts completely open to the mall. After hours, a metal grille is lowered in front of each store to protect it from thievery. The grille, however, does not provide any atmospheric separation between the store and the mall. Consequently, at any time, the stores and the mall they front upon make up one large area through which heat and smoke can travel without interruption.

In most shopping centers there is a large department store at one end, or one at each end. These, called "anchor" stores, usually have a water curtain sprinkler system over their open entrances for protection against fire elsewhere in the mall. Where basements exist, it is also likely that these anchor stores will be well separated from the other stores by a fire wall.

The quantity of water required for control of a well-advanced fire in a shopping center would seem excessive, if not outlandish, to the fire chiefs of many jurisdictions having such shopping centers within their districts. Stores of 400,000 cubic feet in volume are frequently encountered. Such volume calls for a flow of 4,000 gpm. Then, too, there is the problem of reaching the interior with outside streams when the building is over 200 feet deep. There is no easy solution to either problem. The flow rate must be sufficient for the volume of fire, or the fire will continue to burn. The problem of the limited range of the hose stream will have to be overcome by moving the streams inside the building until the fire is reached.

When the water supply is inadequate for an aggressive attack, a strictly defensive battle may be the answer. In this case, the location of fire walls should be noted and efforts directed to prevent the passage of fire past them. The fire walls should be visible above the roof and thus can be readily identified. Their mere presence should not be taken as a guarantee that they will stop the fire. Not only is there a chance of fire getting over the roof parapet, but there have been several cases in shopping centers of fire traveling through small openings in fire walls. Unfortunately, some of these openings may be in concealed spaces above ceilings.

If there are any doorways in the fire wall, the doors should be closed. Combustible material should be moved away from the wall. Hose lines should be brought into the building to be ready to knock down any fire that may get through the wall; other hose lines should be taken to the roof to prevent fire getting over the wall. As the fire nears the wall, use lines to attack it from whatever vantage points are available, with the intention of protecting the wall. In this regard, an aerial stream may prove the most effective.

In shopping centers where sprinkler systems are present, the system should be augmented, as discussed in a previous chapter. In some shopping centers, only portions are sprinklered; therefore an effort should be made to find out which portions are protected and which are not. Also determine if there is more than one system, each with its own siamese, to be supplied.

Other aspects of shopping center fires which are common to all mercantile establishments are discussed in Chapter 15 under "Mercantile Fires."

LUMBER AND OTHER OUTDOOR STORAGE FIRES

Lumber and similar combustible materials stored in piles present several problems when well involved with fire. The large area needed to conduct such businesses causes them to be located at sites where the water supply is sometimes inadequate. The total amount of fuel source is large and requires large volumes of water for control of the fire (Figure 16.39). The large area of the storage yard requires long stretches of hose—often by hand; it further demands advancement of charged hose lines over considerable distances as the fire is attacked.

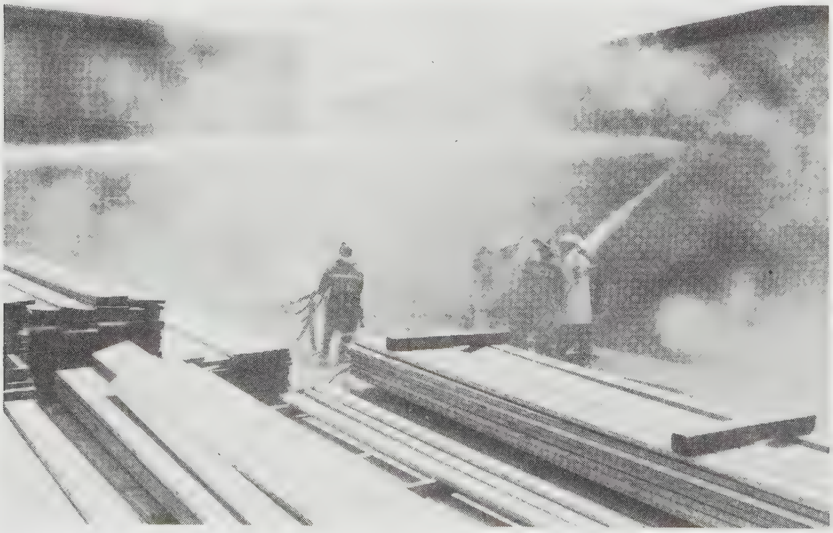


Figure 16.39. *A lumberyard fire, with its tremendous fuel source, calls for great volumes of water, often applied by hand lines that have to be stretched long distances. This photograph shows one area of a seven-alarm lumberyard fire in Washington, D.C.*

Inasmuch as the volumes required call for 2½-inch hand lines, their advance requires sufficient personnel to move the heavy hose lines under adverse conditions.

Multiple Problems

The unlimited air supply to a large amount of combustible surface means that the fire can spread rapidly, aided by the close proximity of the piled material. In addition, the intensity of the fire can cause ignition of nearby buildings by heat radiation. Flying brands are given off in large quantities and can threaten structures several blocks downwind.

Life hazard to others than firefighters is remote, but there is at least one recorded case of fire spreading so rapidly that some people living in frame dwellings across the street from a lumber yard lost their lives.

These fires call for heavy streams with a long reach. At this type of fire, nozzle pressure is more important than at most others. Streams must have sufficient range because the great heat will not allow firefighters a close approach. Use of fog is a waste of water at this type of fire; this fact has not only been noted at actual fires, but proven at a test fire in Memphis, Tennessee.

Steam will be of no value as there is no confinement. Therefore, the streams should be heavy enough to penetrate the hot gases over and around the fire area with a minimum of evaporation and should strike the fuel source in sufficient volume and with force enough to penetrate into stacked material. The ideal rate of flow does not apply here because there is no confinement. Extinguishment is a matter of cooling the fuel sources, and the water must be applied at flow rates which are capable of absorbing more heat than is being generated.

Protecting the Exposures

Exposure protection can be critical and should be given top priority. It takes on three aspects: protection against convection on the downward side of the fire, protection against radiation (radiated heat travels equally in all directions regardless of wind direction), and protection against ignition from flying brands downwind.

The amount of exposure protection required depends upon three major factors: the intensity of the fire, the type of exposures, and their proximity to the fire. Protection will have to be in the form of hose streams. Where other buildings, especially those with combustible walls, are nearby, they should be cooled by water applied to their exposed walls and to roof eaves.

Downwind, where flying brands are a hazard, patrols should single out for attention wood-shingle roofs and outdoor storage of combustible materials as places likely to provide a good host for the brands to ignite; even backyard storage should be considered. It should be realized that when it is impossible to cover every potential exposure downwind, priority should be given to those which would be most susceptible to ignition and those which would be the most damaging if ignited.

In some cases, intense heat may prevent a downwind stand against extension of the fire. In this case, the narrowing flank technique, as described in the discussion of conflagrations, can be used.

Another exposure priority is the building which houses the office of the company whose storage yard is involved. An effort should be made to protect this building because the records it contains may be of much value to the owner.

Trucks and forklifts are often stored in these yards at night. They are quite valuable and should be moved out of danger, if possible. If it can't be done, they should be protected by hose streams, not just because of their value, but because of the possibility of fuel tank explosion. Later, if saved, they could be used in overhaul.

A large storage yard fire calls for strict application of the "confine, then extinguish," doctrine. The judicious placement of hose lines to prevent spread of the fire will limit damage even within the yard. Where the yard contains buildings or sheds, they sometimes become heated to the point where their contents will ignite instantaneously, but there are symptoms that warn of this danger. When lumber stored in an incombustible building is heated by an intense fire outside, it will give off visible smoke before igniting. I saw this happen in a brick-walled storage building; smoke started coming from inside the building, but prompt application of water to the lumber stored there cooled it to the point where it stopped smoking and no ignition took place. The volume of water needed for this purpose is much less than for the extinguishment of the same amount of material. For such preventive measures, 1½-inch hose could be sufficient.

With lumber that is stacked horizontally, the ends of the piles should be protected first because fire penetration at the ends will allow more ready communication of fire to the interior of the pile.

Overhaul is a long-drawn-out process after the fire has been controlled. Whether the storage be lumber or other stacked materials, the burned sections will have to be pulled apart to make sure of complete extinguishment. Mechanical equipment such as forklifts and bulldozers can be utilized, but not in an indiscriminate fashion which would cause a clean-up expense that would add considerably to the fire damage. Water damage is not much of a factor at lumber fires. Therefore, water can be used freely to dig deep into stored material for completion of extinguishment.

NOTES

1. Anderson, B.: Testing High-Rise S.O.P.s. *Fire Engineering*, September 1984, page 57.
2. Chapman, E.: Letter to Editor. *Fire Engineering*, April 1989, page 23.
3. Green, J. D.: *Siren*, March 1971.

Appendix

THE FOLLOWING exercises in firefighting are designed to give the reader of this book an opportunity to apply the principles and practices that were given in the foregoing chapters. The details of each hypothetical fire are spelled out, but the reader can make any reasonable assumption he or she cares to. I know that all readers do not have the same resources within their departments and will tend to think in terms of what they actually have to fight a fire. When they find that the key answer calls for far more equipment or personnel than they would have used, they are urged to expand their thinking and increase their mutual aid—the answers given are based on average or slightly less than average responses in major cities.

The most beneficial way to approach these questions is as follows:

1. Read the entire book up to, but not including, the first exercise.
2. Return to Chapter 5 and memorize the 15 points for formulating a tactical plan.
3. Study Chapter 6 again and memorize the key points of the action plan.
4. Now move ahead to Exercise 1 and study the given information.
5. List the considerations for formulating a tactical plan for this particular exercise.

6. Formulate an action plan to be applied to the problem given.
7. Move on to the key answer and compare your answer to that.
8. Repeat this procedure with the other exercises.

EXERCISE 1: A ONE-FAMILY HOUSE

You are in command of a first-alarm assignment of two engines (each 1,000 gpm) and one ladder company at a fire in a one-family wood-frame house. It measures 20 × 40 feet, is 2½ stories high, and has a full basement and an attic. You arrive at 2:30 A.M. on a February morning. The temperature is 10 degrees above zero, a red glow is showing through the living room windows, and smoke is issuing around all windows and doors and from the eaves of the roof. The house is a short distance from the street, and a six-inch main with a hydrant is located 150 feet away from it. See Figure A.1.

A. Size up this fire, listing the tactical considerations.

B. Give your action plan for this fire. Do this by putting companies to work on the components of the plan which have to be carried out.

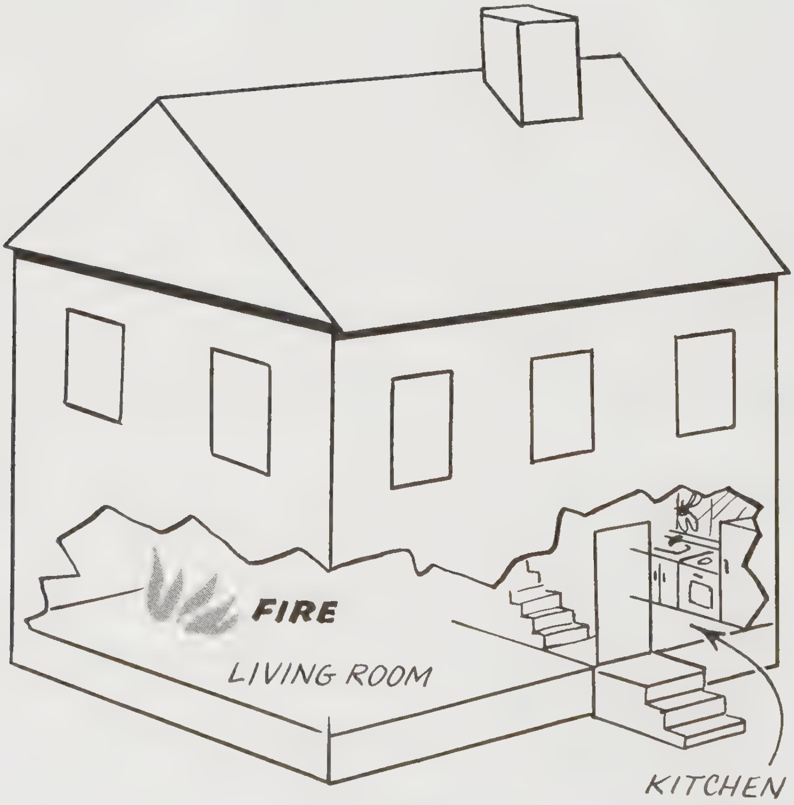


Figure A.1.

Tactical Considerations

1. *Location:* The glow in the living room indicates the location of the main fire. This placement means that fire can extend vertically and horizontally and that smoke and products of combustion threaten the lives of all occupants on or above the same level.

2. *Extension probability and possibility:* The immediate probability of the extension is to other rooms on the same floor, particularly if there are doors open. If this condition will allow the fire to reach the stairs, fire will soon travel upward by way of the stairwell; fire can also get into ceiling spaces for horizontal travel, and side walls for vertical travel. Extension to other buildings is not likely.

3. *Life hazard:* The life hazard is probably severe, because at this time of night occupants may be sound asleep and unaware of the fire. The amount of fire involvement indicates that carbon monoxide and other fire gases have been given off in quantity and may have affected the occupants. It is highly likely that the building is occupied, and if the occupants are not calling for help, they may be overcome by gases, but still alive. The most likely location to find them is either in bed or not far from it.

The life hazard to the firefighting force is minimal at this type of fire. All rooms have windows; no part of the building is far from an exit. Because of its size, there is no danger of firefighters getting lost in the building. Structural failure is not a probability. The principal hazard is smoke, and firefighters' exposure to it will not be of sufficient duration to exhaust the initial air supply in their breathing apparatus. There should be no danger to spectators if they are kept more than 30 feet or so from the fire building. The building is not likely to explode or present any other unexpected danger.

4. *Time:* The time of day indicates that the occupants were probably in bed, asleep, when the fire was discovered. Some may still be there. Also the time of day indicates that the fire has been burning for a considerable period. The time also establishes that it is dark, and artificial illumination will be necessary to provide efficiency and prevent accidents. (In some volunteer departments it may mean a slower response but more personnel. In some paid departments, it may mean a quicker response because of less traffic.) The time of the year (February) indicates a dried-out building and contents because of the heating season, which could cause fast fire travel.

5. *Weather:* Inasmuch as the question has not mentioned wind, it will be assumed that wind is not a factor; however, the temperature

of 10° above zero suggests the possibility of frozen hydrants and also the handicaps imposed by ice formation and the cold upon the firefighters. Firefighter movements will be slowed by bulky clothing and crews will be subject to injury from cold or slipping on ice. Hose lines cannot be completely shut down for fear of freezing.

6. *Construction:* The appearance of the dwelling lends a strong probability to its being of balloon-frame construction. Therefore, upward extension of fire via side walls is likely. The structure has an attic to which fire may spread via side wall spaces. This type of building offers little resistance to fire spread and provides many fuel sources which enable a fire to increase rapidly in volume. Walls are probably of plaster on wood lath, on wood studs. Fire-stopping may or may not be present between studs. The plaster may resist the fire for 20 minutes or so, a point which may already have passed. If fire gets into the attic, it will have the whole under side of the roof as a fuel source to generate an intense fire.

7. *Height:* The height of this building is so small as to present no problems.

8. *Area:* The area of this building is so small as to present no problems.

9. *Occupancy:* The building is occupied as a single-family dwelling; therefore, people may well be in there. The occupancy does not denote any exotic or dangerous materials, but there will be a considerable amount of combustible furniture.

10. *Access:* There is no problem in gaining access. The house is only a short distance from the street and is not obstructed in any way. The types of doors and locks can be forced; so can the windows. All doors and windows can be reached without difficulty.

11. *Internal protection:* None.

12. *Water supply:* There is a six-inch main with a hydrant only 150 feet from the building. There should be adequate volume for this fire without having to use another hydrant or pumper, but it would be well for the second-due engine to connect to another hydrant and stand by as a precautionary measure.

13. *Apparatus:* The two pumping engines should be adequate for this fire. Even if the fire extends throughout the building, two 1,000-gpm pumpers can easily supply the necessary flow. The one ladder truck certainly has all the ladders and tools needed for this sort of fire.

14. *Personnel:* The reader must answer this in terms of his own normal resources available, because of the differences that exist among fire departments.

15. *Terrain:* Since no mention is made of terrain, there is no need to consider it as significant.

Action Plan

1. *Finding the fire:* The fire is visible in the living room. It may be extending elsewhere but, until there are indications of its being elsewhere, actions should be predicated on its apparent location.

2. *Rescue:* Inasmuch as there are no persons calling for help or apparently in immediate need of help, rescue will have to depend upon what needs are disclosed by search. There is a probability that if the occupants were at home they may have been overcome. If some occupants have escaped, they should be questioned to find out if others are still inside and where they could be found.

3. *Search:* Search should be prompt and thorough. The truck company should raise ladders to second-floor windows and attic and thoroughly search both of these areas. The attic may contain a bedroom and, if it does, this would be the location most dangerous to life because smoke and gases will accumulate there. Members of the second-due engine should assist the ladder company in this search. Additional search should be made by forcing the rear door and entering the ground floor. Members searching for victims can also search for extension of fire. All findings should be reported promptly to the officer in charge.

4. *Safety:* The main hazard to firefighters at this fire is smoke. Breathing apparatus should be worn by all those entering the building. The building is easy to ventilate, and the smoke problem should be relieved quickly. The fire should be extinguished well before initial breathing air supplies are used up. Officers and crew searching should carry handlights, and other lighting should be provided as soon as feasible.

Because of the cold, ice will soon form and firefighters are liable to slip and fall. They are also in danger of frostbite. Officers should be told to guard against these injuries.

Structural collapse is not a factor. The occupancy denotes no dangerous contents or processes. Explosion is highly unlikely; however, the fire may flare up suddenly when ventilation begins.

5. *Communications:* A preliminary situation report should be transmitted to headquarters by radio, giving such facts as type of building, size of building, exposures, special problems if any, and whether or not it is likely that more apparatus, equipment, and personnel will be needed. (In this case it would not.) Radio communication by hand portable transceivers should be set up between the chief and officers of each of the companies present.

6. *Extension protection:* If you find that the fire has extended to the second floor, it will have to be handled by taking the first line

there as soon as it has knocked down the first-floor fire (which should not take long). The immediate stretching of a second line is not feasible because the second-due engine company is engaged in the search for occupants. When they have completed their part of the search, they can stretch a second line, if necessary. If the officer of the first-due engine is carrying a bent tip, it can be affixed to the nozzle, the nozzle inserted into the side wall, and the stream directed upward after fire in the living room has been extinguished, and it appears that fire has entered the wall.

If fire has entered the side walls and is threatening the attic, a line should be taken to the attic. If it is an open attic with a hatch opening on the second floor, the line should be taken up a short ladder into that opening and the stream swept around the perimeter of the attic so that the water can run down the walls and extinguish the fire in the wall spaces.

7. *Call help:* Not necessary in this case. It is assumed that no special equipment is needed; pumping capacity is more than adequate, and so is personnel.

8. *Ventilation:* There should be no need to cut a hole in the roof. Ventilation can be performed by the ladder company opening attic windows from ladders, and the second-due engine company as well as the ladder company opening windows from the inside as they search on the first and second floors. The living room windows should be opened as soon as water is at the nozzle. If the living room windows cannot be opened quickly, they should be broken.

9. *Entry:* A member of the ladder company should force the front door and remain with the engine company to open up for them as needed. Another ladder company member should force the back door so that firefighters can enter for search.

10. *Extinguishment:* A hose line should be taken immediately to the front door and advanced into the living room as soon as the door has been forced and water is at the nozzle. A hose line of 1½-inch diameter is sufficient for this fire and will give easier mobility if the charged line has to be taken upstairs after knocking down the fire in the living room. After the main body of fire has been knocked down, the line shuld be taken to where other fire may be showing.

11. *Salvage:* If there are a sufficient number of personnel, some firefighters should be sent immediately into the basement with covers to protect any articles from water damage. The amount of water needed for this fire is not great, and water run-off would not ordinarily be a problem.

If it is necessary to pull down ceilings—and it probably will be, to some extent—undamaged furniture and articles should be covered or moved out of the area. Small articles on dressers can be swept into drawers and the drawers closed. Pictures should be removed from walls and placed in a safe place. If water has accumulated in the ceiling, a tiny hole should be made to relieve it.

Before leaving the premises, plastic film should be affixed over the windows that have been broken.

Any articles of value found should be turned over to the occupant. If he or she is not available, then the departmental policy (state whatever it is for this situation) should be followed.

12. Cooperation of other agencies: The only help that might be needed at this fire would be medical care for the injured. If it turns out that there were occupants in the building and that they were overcome by smoke, medical care would be summoned immediately by radio.

If there is suspicion that the fire may have been set intentionally, departmental procedures for such a situation (state them) would be followed and care taken to preserve evidence.

Note: It isn't likely that this fire would require the notification of public utilities such as the gas, electric, and telephone companies, but if it was found necessary, they would be notified. If the premises are to be left temporarily without occupants, the police would be notified. If occupants are made temporarily homeless, the welfare department should be notified.

13. Overhaul: The overhaul would be divided into two categories: contents and structure. The engine company would be given the task of overhauling the contents and the ladder company the structure. A charged hose line would be kept in the area being overhauled, ready for instant use should fire flare up, and to extinguish any embers or smoldering fire discovered during the overhauling.

If upholstered furniture is burned, it would be cut open and the stuffing removed until no burned material remains. The burned part would be shoveled up and taken out of the building to a place in the yard where it could not cause damage by rekindling later.

Burned clothing would be separated from unburned and placed to soak in a washtub or bathtub.

The structural overhaul would involve opening the ceiling of the living room, to ascertain if any fire had entered the ceiling space, by putting a small hole near a light fixture or other natural opening or at a spot where heat might have been conducted through the ceiling. The hole would be enlarged if any evidence of char was discovered and would be enlarged continually until no more char was seen.

If discoloration or blistering indicates a possibility of fire in side walls or if a wall is still excessively hot, it would be opened and, if char shows, the same procedure as that mentioned for the ceiling would be followed. If an examination is indicated for the second-floor wall, the baseboard would be removed and a hole punched in the area covered by the baseboard, so that, if no further opening is necessary, the baseboard can be replaced and the hole covered.

Broken lath and plaster would be shoveled outside and excess water removed from the floor with squeegees.

Note: Before overhaul gets under way, an attempt should be made to determine the fire cause. If there is an indication of arson, care should be taken to preserve evidence and not to disturb anything that would be of value to investigators.

Before leaving the premises, a final search would be made on all floors for any live smoke or other evidence of remaining fire. The opened windows would be closed and the hose line taken outside for a final soaking of the burned materials which had been taken there.

Note: Due to the cold weather, it will be necessary to keep the nozzle open slightly at all times to keep the water in the hose from freezing. During the overhaul period, the hose should be placed out of a window so that the water coming from the nozzle will not cause damage. A very slight flow should be sufficient to prevent freezing in the hose at 10°F.

EXERCISE 2:
A SMALL DEPARTMENT STORE

This fire occurs at 3 P.M. on a weekday with the temperature at 92°F and a strong breeze blowing from the east. The fire building is an ordinary two-story brick wall and wood joist structure two stories high and 25 × 80 feet in width and length, which was erected in 1875. The other buildings in the block are of the same type of construction and were built in the same era. The occupancy of the fire building is a department store on the street floor and offices on the second floor. The basement is used by the department store, which has an open stairway in the center that leads to the basement. All stores in the block have entrances to basements from a flush metal door set in the sidewalk.

Upon arrival of the first-alarm assignment of two engines and one ladder company, it appears that the fire is in the basement of 130 First Avenue. Dark smoke is rapidly filling the store and seeping out the front door. See Figure A.2.

A. Size up this fire, listing the appropriate tactical considerations.

B. Give an action plan for this fire, stating in the first person the orders you would give, and the reasons for them. For instance: "I would order the first-due engine company to . . ." (and give the order).

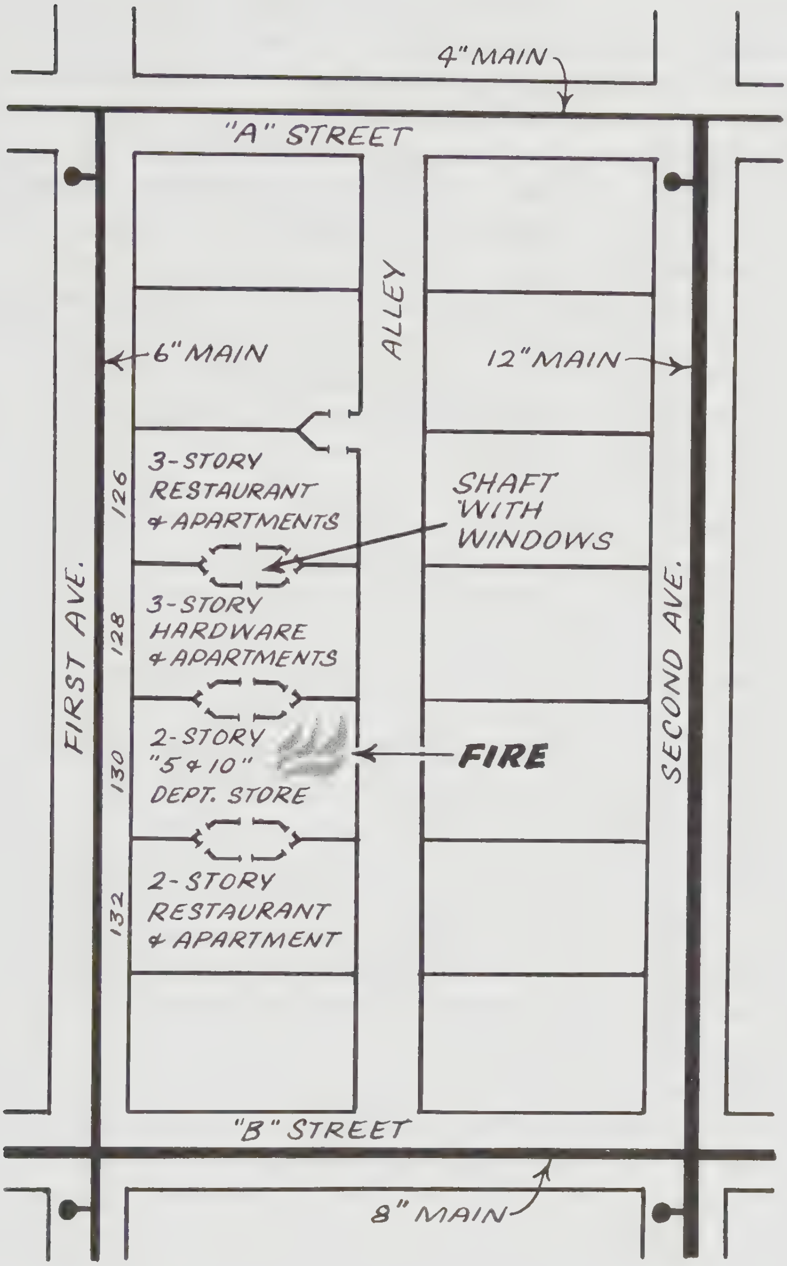

4" MAIN
"A" STREET
6" MAIN
ALLEY
12" MAIN
3-STORY RESTAURANT & APARTMENTS
126
SHAFT WITH WINDOWS
FIRST AVE.
3-STORY HARDWARE & APARTMENTS
128
2-STORY "5 & 10" DEPT. STORE
130
FIRE
SECOND AVE.
2-STORY RESTAURANT & APARTMENT
132
"B" STREET
8" MAIN

Figure A.2.

Tactical Considerations

1. *Location:* The given facts indicate that the fire is in the basement of the department store.

2. *Extension probability and possibility:* Since fire usually travels upward, the street floor and second floor of the fire building are vulnerable to extension. Inasmuch as there is an open stairway from

the basement to the street floor, heat will rise through that stairway and may soon bring the temperature on the street floor to the ignition point of some of the material stored there.

Horizontal extension to other buildings is worth considering. It is possible that 132 First Avenue was built at the same time as the fire building and may have beams abutting it through a party wall. Therefore repeated examination should be made in 132, until danger of extension is past.

Examination should be made also in the basement of the building on the other side, 128, but here is another problem. This building is one story higher than the fire building and, if it has windows on that side, fire breaking through the roof of the fire building could enter the third-floor windows of 128.

Of particular concern is the shaft on the west side of the fire building. If the fire extends to this shaft, it could enter 128 through the windows on the shaft.

Extension via cockloft is impossible to 128, but quite possible to 132, which is the same height as the fire building. The cockloft might be common to both buildings, but this fact could be detected by a look at their fronts.

There is not much likelihood of the fire jumping across the alley to the buildings in the rear, but the possibility should not be disregarded completely.

3. *Life hazard:* The given facts do not mention any immediate life hazard, and the assumed life hazard therefore would be none to occupants. The described condition indicates that all have had ample opportunity for escape, but perhaps the people in the second-floor offices have not yet learned of the fire and should be warned to evacuate. The life hazard to firefighters is from smoke and potential structural failure. There is no life hazard to others.

4. *Time:* The time of day is favorable. It is during daylight hours, and no problems are presented by the time. All occupants should be awake and alert. There is not the handicap of working in darkness; artificial lighting is not needed.

Some volunteer departments would, however, find a critical personnel shortage at this time of day and would have to make up for it by immediate calls for mutual aid.

5. *Weather:* The extreme heat can cause problems. Personnel may suffer from heat prostration. Open windows downwind may allow brands to enter and start other fires. The wind will blow brands for a distance if the fire breaks through the roof.

6. *Construction:* The age of the building is cause for concern. It is the brick wall, wood joist type built right after the end of the Civil War; it will offer little resistance to fire. It is old, and the brick walls

are bonded by lime mortar; therefore they are prone to collapse. The wood joists are old and dry and may burn through to a point of weakness in 20 minutes or so. Collapse of the first floor in a short time could occur.

The open stair from basement to first floor gives the fire an opportunity to travel upward with no resistance. It is probable that this building has in a rear corner a dumbwaiter shaft which goes from basement to second floor and which will provide another vertical path for fire travel.

Buildings constructed in the period when this one was erected provide much fuel and little resistance to fire spread. Deterioration due to aging makes them more combustible and weaker.

7. *Height:* The height of the building presents no problems of access or laddering.

8. *Area:* The area is not excessive and poses no problems.

9. *Occupancy:* (It is suggested that the reader take a walk through such an occupancy and note all the contents.) The type of retail store contained in this building has a varied stock, which includes several flammable and combustible materials, both liquid and solid. Such items as charcoal lighter fluid, lantern fluid, paint thinner, and paints are present in quantity. Readily combustible solids are also present in large amounts. There is a large assortment and a substantial quantity of combustible materials.

10. *Access:* In this case there is ready access to all floors of the fire building, both interior and exterior.

11. *Internal protection:* None of value.

12. *Water supply:* The six-inch main on First Avenue will be good enough for 800 gpm but may not be dependable for a flow of more than that. Other than the first-alarm engines should use the 12-inch main on Second Avenue.

13. *Apparatus:* Two engines and one ladder will not be sufficient if this fire gets out of the basement. Additional aid should be summoned forthwith.

14. *Personnel:* The personnel are again determined by the local policy for a first-alarm fire of this type. Its sufficiency or deficiency should be figured accordingly. There should be enough firefighters to stretch six 2½-inch lines and for frequent relief due to the hot weather and severe fire.

15. *Terrain:* It should not have to be considered at this fire.

Action Plan

1. *Find the fire:* The evidence points to a fire in the basement.
2. *Rescue:* It appears that there is no problem. All occupants

have had time to evacuate, and the building should be empty of human tenants.

3. *Search:* Search in this case will be largely for extension of the fire, but it should not overlook the possibility of a trapped occupant.

I would order the ladder company to search the second floor of the fire building for endangered persons and extension of the fire, and then search the basements of the adjoining buildings on both sides for signs of fire extension and to estimate its probability. I would have the air shafts examined to ascertain what stories of 128 and 130 have windows on them.

4. *Safety:* All personnel working in the fire building should wear breathing apparatus, and there is strong likelihood that initial air supplies will be exhausted. Care should be taken that firefighters do not stay inside to a point where they run out of air. I would guard against this by ordering frequent relief; this pause would not only allow a firefighter to note the amount of air left but would allow rest, which is especially necessary because of the hot weather. There is likelihood of heat prostration with the temperature at 92°F.

I would call for additional air supplies immediately so that they would be on hand as soon as needed.

There is a probability that the floor above the basement may collapse if the fire is not brought under control in 20 minutes. This collapse would occur if the joists burned through to a point where they could not longer sustain the heavy floor load of counters and stock, which could be fatal to firefighters in the basement and on the first floor. Therefore if the fire is still out of control 20 minutes after arrival, I would order the withdrawal of all personnel and shift from interior attack to exterior attack and strong defense.

5. *Communication:* I would send a preliminary situation report to headquarters via radio. Field radio communication by hand portable transceivers would be established between me and each company officer present so that they can receive my orders and I can obtain from them information on which to base my decisions.

6. *Extension protection:* The greatest probability of extension is up the open stairway to the street floor. I would order the first-due engine to take the first line into the store to keep the fire from extending by that stairway. They would take the nearest hydrant and lay two 2½-inch lines simultaneously, one line for the second-due engine company, as indicated below under extinguishment.

The third-arriving engine company would be ordered to take the hydrant at Second Avenue and B Street and stretch a 2½-inch line through the alley and into the rear entrance of 128. They would be told to guard against extension by way of the shaft or basement by having firefighters watch both places so that the line can be taken to any point fire is attempting to enter.

I would place another line, when available, into the rear of 132 to guard against extension there by way of the cockloft or basement and would have a constant watch kept in the basement and both stories of that building so that, if fire enters it, a line can be moved quickly to the point of entry.

Of course, I would have repeated examinations made by ladder company members in both adjoining buildings and, if conditions warrant it, additional lines would be stretched to those buildings.

If the fire has taken possession of all floors of 130, I would call additional help and have additional lines stretched into both exposed buildings. If the fire breaks through the roof of 130, it will probably be necessary to keep it from entering the third-floor windows of 128.

7. *Call help:* I would immediately call for four additional engine companies and two more ladder companies for a total of six engines and three ladder companies. (The reader would, of course, follow the procedures of his or her own department to accomplish this.) This amount of help is needed because of the exposure problem as well as the nature of the fire building and its contents. (At this point in many cities the third ladder company would not be available. It is not essential because two ladder companies would provide the necessary ladders and tools. But it is essential to provide the personnel who would be needed to pull down ceilings in the adjoining buildings, if that becomes necessary, and to cut holes in the floor for cellar pipes.)

8. *Ventilation:* I would order the first-due ladder company to ventilate by opening all windows at the rear of the fire building and by removing the roof-level coverings such as skylights and scuttle covers. The second ladder company to arrive would be ordered to open the remaining windows, except those on the shaft. If the engine company in the store was experiencing difficulty due to smoke and heat, I would order the glass broken out of the show window and the partition behind the show window knocked out.

If conditions eventually warranted it, I would order a large hole cut in the roof of the fire building, but not where it might subsequently jeopardize the top floor of 128.

9. *Entry:* Forcible entry should not be necessary to gain access to the involved areas at this time of day. Doors would be unlocked during business hours; however, the steel door to the basement may be locked with a padlock, which may have to be forced. Tools should be ready to cut holes for cellar pipes, and to open ceilings in the adjoining buildings if it becomes necessary.

10. *Extinguishment:* As already stated, the first line was sent to the top of the open basement stairway to prevent upward extension. I would order the second-due engine company to take the second line which had been laid by the first-due engine. When it was charged with water, I would have them take it into the basement of the fire

building by way of the stairs from the sidewalk. The outcome of this fire would probably depend upon the success of this line. If they could get quickly to the bottom of the stairs and enter the basement, and if they could sweep a good portion of the basement from that point, the situation would be under control in a few minutes. If they are unable to do this, the situation would have to be handled differently.

[*Note:* In real life, this incident would be an instance where pre-fire planning would prove valuable. It would be ideal to know in advance if this company would have an unobstructed sweep of the basement from the foot of those stairs or whether they would be in a room, behind partitions, or otherwise obstructed.]

I would order the fourth-arriving engine to stretch a 2½-inch line to the rear entrance to the store floor of the fire building, attach a distributor nozzle, and be ready to use it through a hole in the floor which I would order the first-due ladder company to cut for them. If the line into the basement from the front was able to advance without difficulty, I would withhold the distributor, but if they couldn't move, I would order it started.

At this point I feel that these tactics would be successful, but if the line in the front of the basement was not advancing I would determine why, and, if rapid advance seemed impossible, I would order withdrawal of that line and convert it to another distributor nozzle to be operated from a hole near the front of the store. The reason for choosing distributors over cellar pipes is that they can be left in place if personnel have to be withdrawn for safety reasons.

If the situation worsened to a point where the first line had to be withdrawn because of the store heating up to a dangerous level, or the probability of the floor collapsing, I would order a deluge gun placed in the front entrance of the store to sweep the ceiling constantly in order to keep the store area from reaching ignition temperatures.

11. *Salvage:* Salvage operations at this fire would be rather limited, but if it were necessary to open ceilings and apply water in the adjoining buildings or on the second floor of the fire building, I would order the furniture and stock covered with tarpaulins. If there is a deep accumulation of water on the basement floor after the fire is extinguished, I would have it removed with a dewatering device.

12. *Cooperation of other agencies:* The police department would have to provide crowd control inasmuch as this fire is in a mercantile district on a business day—probably the only notification or request made during the progress of the fire. After the fire was well under control, I would notify the health department if the department store

had food for sale, or if there was fire extension or heavy smoke damage in the adjoining restaurant. I would also notify the electric company and gas company if either of those services had to be cut off or was affected by the fire.

13. *Overhaul:* If the fire was confined entirely to the basement, I would attempt to discover the point of greatest burning and have the overhaul radiate outward from there, with the first-due ladder company working toward one end, while the second-due ladder company worked toward the other, because the burning usually diminishes with the distance from the point of greatest intensity.

Care would be taken in moving contents because cans of paint and other liquids may have been weakened by the heat and could fall apart, spilling flammable liquids where embers may still be glowing.

Due to the weather, I would call for additional firefighters to relieve those who had worked until the fire was brought under control. I would give orders that all of them were to be rested frequently to avoid illness from the heat.

I would make sure that all burned stock is examined closely for signs of remaining fire and wet down, if necessary. When overhaul is starting, I would have a length or two of 1½-inch hose attached to the nozzle of the 2½-inch line for easier mobility. This line would remain in the basement for use as necessary. In moving stock, care should be taken that the line is not buried, especially when it is not noticeable because it is covered with water.

I would use engine company members to assist ladder companies in moving stock, but I would not retain more than two engine companies and two ladder companies for the overhaul, so the others could go back into service as soon as possible. When the overhaul was about half completed, I would dismiss all but one engine company and one ladder company.

When overhaul was about to get under way, I would have the line from Second Avenue and A Street connected to the overhaul line so that the other lines could be removed to allow traffic to flow again. The pumper there would remain on the hydrant but would be shut down to save wear and fuel. If the fire flared up and more pressure was needed, the pumper could be started quickly.

Before leaving the scene, I would ascertain that the owners or police had made provision for guarding the building, and I would make a last tour of inspection throughout all affected portions of all three buildings, 128, 130, and 132, to make sure that the fire was completely extinguished, or to effect further salvage or restoration of the building.

EXERCISE 3: A HOSPITAL

You respond at 2:00 A.M. to a fire in a children's hospital where approximately 200 people are housed in a building erected in 1868. The building construction is the typical brick wall, wood joist construction of that era. It is five stories high and irregularly shaped as shown in Figure A.3. In later years, fire walls were built in two places, as shown.

The fire is in the laundry room in the basement at the northeast corner of the building. The fire is burning intensely, and smoke is showing at the roof eaves.

A. Size up the situation, giving the factors influencing your choice of tactics.

B. Give an action plan for this fire, assuming that you are in charge of a first-alarm assignment consisting of three engine companies and two ladder companies.

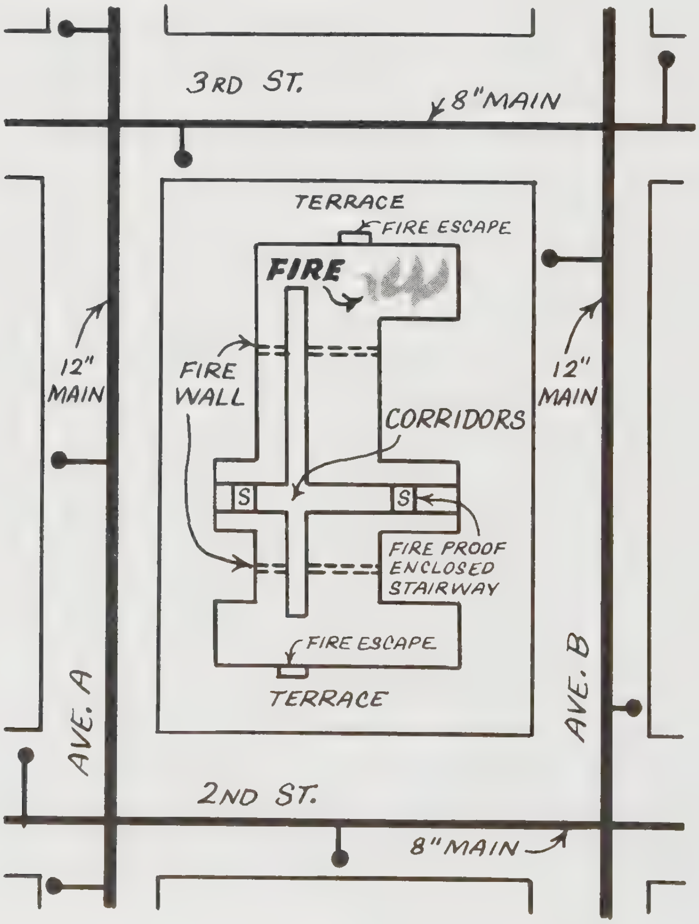

3RD ST.
8" MAIN
TERRACE
FIRE ESCAPE
FIRE
FIRE WALL
12" MAIN
12" MAIN
CORRIDORS
S
S
FIRE PROOF ENCLOSED STAIRWAY
FIRE ESCAPE
TERRACE
AVE. A
AVE. B
2ND ST.
8" MAIN

Figure A.3.

Tactical Considerations

1. *Location:* The fire is located in one corner of the basement and therefore is free to travel upward for five stories, and horizontally at least to the fire wall. It could well endanger nearly all of the 200 occupants, especially through the vertical travel of smoke and toxic gases.

2. *Extension probability and possibility:* The intensity of the fire indicates a strong probability of extension. It may travel vertically through wall spaces or even by burning through the wooden floor above the basement. It is probable that it will extend horizontally along the basement ceiling. This building may also contain large ventilating ducts which could carry the fire throughout. The fact that smoke is showing at the eaves is an indication that smoke and heat can rise to the attic. Fortunately, there are no nearby buildings to become exposed.

3. *Life hazard:* The life hazard is extremely severe due to the number of people in the building and above the fire. It is complicated by the fact that most of them are children and are ill. The usual nurse-to-patient ratio is not sufficient to assure quick evacuation. Smoke will probably permeate the building, cutting off visibility and causing panic.

The life hazard to the firefighting force is serious. Due to the rescue problem, firefighters will go deep within the building to search for and remove occupants. They may be trapped by fire or overcome by fire gases.

There is a potential for structural collapse due to the age and type of the building and the intensity of the fire, but this problem is not likely in the early stages of the fire.

4. *Time:* The time is unfavorable. Occupants will be asleep. The hospital work force is at minimum strength and consequently less able to aid evacuation. Darkness will complicate matters due to reduced visibility. Artificial lighting will be badly needed.

5. *Weather:* Since weather was not mentioned, it will be assumed that the temperature is mild and the wind very slight. (*Note to readers preparing for promotional examinations:* If the question allows such assumptions, why complicate the problem?)

6. *Construction:* The very age of the building is cause for deep concern. Many of the key structural members are of wood, which has been drying for over a century. This type of structure contains many voids and channels for the vertical and horizontal travel of fire. It was built when little thought was given to fire safety and will offer fuel sources rather than fire resistance except for the two recently added fire walls. The attic is most likely undivided over the entire building.

7. *Height:* The upper stories are beyond the reach of 35-foot ladders and it would be difficult to reach them with aerial ladders because the terrace will not permit access for the ladder trucks; however, 100-foot aerial ladders can reach the roof of the wings from Avenue A.

8. *Area:* The area is large, but the portion between the fire and the nearest fire wall is about 6,000 square feet (about 60 × 100 feet).

9. *Occupancy:* As mentioned under life hazard, the occupancy presents a vast rescue and evacuation problem, but it does not contain any serious amount of dangerous materials or processes.

10. *Access:* The terraces limit access by apparatus. Ladders must be hand-carried for short distances.

11. *Internal protection:* If the building had an adequate sprinkler system, the fire would not have gained such headway; however, I would have an examination made to discover any siamese connections and, if any were found, I would determine what they supplied and act accordingly. (Pre-fire plans should indicate what internal protection is present.)

12. *Water supply:* Figure A.3 shows that the building is surrounded by nine hydrants on cross-connected mains of good diameter.

13. *Apparatus:* The three engines may be sufficient to contain the fire if an attack can be mounted quickly enough, but there is doubt that this can be done. The big need is for ladders to rescue occupants who become trapped.

14. *Personnel:* There is need for additional firefighters to assure safe evacuation of the child patients.

15. *Terrain:* The terraced area surrounding the building makes access and laddering difficult and keeps aerial ladders and platforms at a distance that limits their usefulness.

Action Plan

1. *Find the fire:* The fire is showing in the northeast corner of the basement.

2. *Rescue:* I would order the majority of the first-due ladder company and all of the second-due engine company to start evacuating patients horizontally.

If the patient load is distributed according to the size of each area separated by fire walls, there would be about 50 patients in the affected portion.

The hospital should have an evacuation plan and the staff has probably put it into effect by now, but the firefighters should help them. If there are people seeking assistance at windows, I would have the second-due ladder company raise ladders to them. But the emphasis would be put on horizontal exit, moving patients, beds and all when necessary, through the fire doors to the other end of the building and then down and out of it, if that became necessary.

3. *Search:* I would have second-alarm units search all floors in the fire wing to make sure they had been completely evacuated. As they did so, they could also look for signs of fire extension.

4. *Safety:* The operating force on the first alarm will have to sacrifice some safety in order to assure prompt rescue and attack on the fire; however, as soon as rescue has been completed, safety rules would be observed and precautions taken against the hazards already listed.

5. *Communication:* A preliminary situation report would be sent by radio to headquarters outlining the problem briefly and requesting additional help.

Communications between me and all officers present would be established by hand portable transceivers.

6. *Extension protection:* Some extension protection would be sacrificed by using the second-due engine for rescue purposes; however, the third-due engine would be ordered to stretch and operate at any point where fire was found to be traveling. I would order all fire doors closed promptly after completion of evacuation from the involved section. I would order the immediate closing of the door (if open) in the basement fire wall.

7. *Call for help:* I would immediately call for four more companies (by whatever method your department uses) mostly in case they were needed to speed the rescue work. I would specify that at least one of these be a ladder company because more ladders might be needed.

8. *Ventilation:* I would send two firefighters to the roof by way of fire escapes or other available means, to ventilate there by removing coverings from the tops of vertical arteries in the involved portion of the building. They should examine the cockloft for signs of fire and then descend, ventilating at the windows of the top floor and other floors on the way down. The second-due ladder company would be ordered to knock out all the windows in the involved portion of the basement.

Smoke ejectors would be set up to keep smoke out of uninvolved portions of the structure.

9. *Entry:* There is no indication of a need to force locked doors. Need for other types of forcible entry is not likely.

10. *Extinguishment:* The first-due engine company would be ordered to take a 2½-inch line into the basement through the door nearest to the fire, in order to knock down the fire as quickly as

possible. It is likely they would knock down this fire in two or three minutes after getting water to the nozzle. (They would connect the pumper to the hydrant at Avenue B, south of Third Street.)

The second-due pumper would take the hydrant on Third Street, east of Avenue A. The third-due engine company would connect to the hydrant on Third Street near Avenue B and stretch two lines, one to the area immediately above the fire and the other to stand by.

11. *Salvage:* Rolled covers would be placed in basement doorways to prevent water from the fire area from entering the other parts of the basement (when time permits).

12. *Cooperation of other agencies:* None should be needed here.

13. *Overhaul:* Overhaul activities would include close examination of all vertical arteries all the way to their tops and scrutiny of wall spaces above all fire. The ceiling of the laundry room would be pulled down as soon as possible because of the strong likelihood of the fire extending into the ceiling space. I would also have the attic checked for signs of fire or live smoke. Due to the nature of the occupancy, I would have a scrupulous re-examination performed throughout to make sure that there was no chance of rekindle before leaving the premises. As an added precaution, I would leave a firefighter on the premises to keep alert for any rekindle until his or her tour of duty expired, at which time I would come back to pick him or her up and take another look around.

EXERCISE 4: AN OLD-LAW TENEMENT

A fire occurs at 430 Avenue X in a five-story and basement old-law, brick tenement (apartment) house. The block is completely built up with such tenement houses, most of which have shops or stores in the basements. There are light and air shafts between each building. The neighborhood is densely populated by foreign-born people. The house has a composition roof and non-combustible cornice; fire walls extend 30 inches above the roof. There are four apartments on each floor; those at the front have four rooms, those in the rear three rooms. Backyards in the block are enclosed by high board fences; there is a confused maze of clotheslines above them. Fire escapes have some obstructions, and tenants have boarded over some of the balcony openings so that their babies may sleep outside the windows.

The fire started in a carpenter shop in the basement and was discovered in the hall of the street floor at 9:30 P.M. When you arrived with a ladder truck five minutes later, the halls were full of smoke. See Figure A.4.

Your assignment on the first alarm is composed of three engine and two ladder companies.

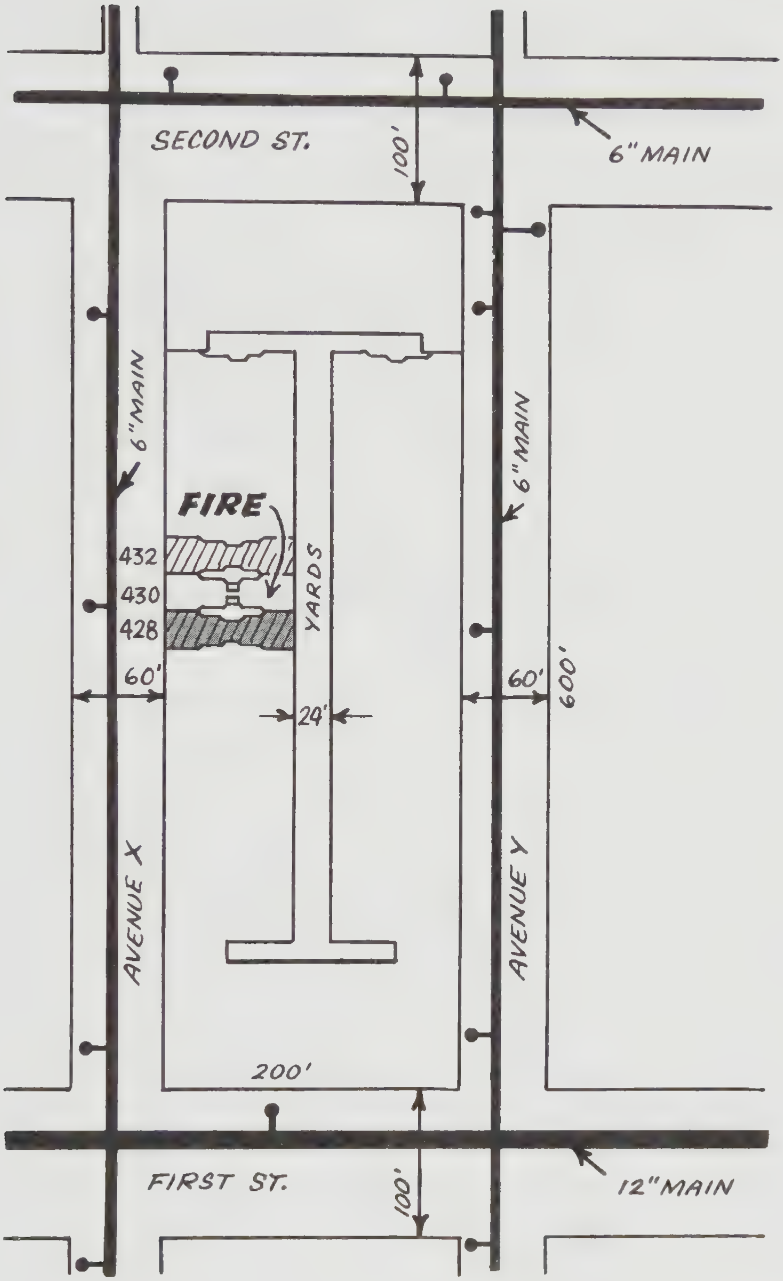

SECOND ST.
100'
6" MAIN
6" MAIN
FIRE
432
430
428
YARDS
6" MAIN
60'
24'
60'
600'
AVENUE X
AVENUE Y
200'
FIRST ST.
100'
12" MAIN

Figure A.4.

A. Size up this fire, giving the factors influencing tactics.
B. Give an action plan for the first ten minutes after arrival.

Tactical Considerations

1. *Location:* The fire started in the basement; therefore all portions of the building are subject to fire travel. Since smoke and toxic

gases will rise throughout the building, tenants are endangered on all floors. Fire has already reached the ground-floor hall, which means it is on its way up the stairs.

2. *Extension probability and possibility:* The most likely immediate means of extension is by way of the interior stairs, but, if the fire breaks into one of the shafts, it could spread to adjacent buildings through windows on the shaft.

3. *Life hazard:* The life hazard is great because probably more than a hundred people live in this building and many of them would be home at this hour. The stairway is filled with heat and smoke, rendering it useless as a means of egress. Fire escapes provide secondary egress from each apartment, but the fire escapes are obstructed on some floors. There is probability of panic, and some persons may jump. The top floor is especially vulnerable because of mushrooming.

4. *Time:* The time indicates many people will be in the building. It also connotes darkness. Visibility will be decreased. Artificial lighting should be provided to reduce injuries and improve efficiency.

5. *Weather:* Since weather is not specifically mentioned, it will be assumed that it is not a factor here.

6. *Construction:* As an old-law tenement, the building would have wood joists, wood floors, and an open wooden stairway. The doors to the apartments may have glass panels which would break when heated and allow fire to enter. Even if they are not glass, the doors are not self-closing, and if left open would permit fire to enter. Glass transoms over doors also permit the passage of fire.

The walls of a building five stories high would be of brick, but communication to adjoining buildings is possible because of the light and air shafts.

There is undoubtedly an inside stairway from the first floor to the basement which allowed the fire to reach the hall, from which it will travel upward throughout the stairway all the way to the roof. The age of the building indicates the hallways must have many layers of paint, which will provide a source of much fuel. In general, the building has very little resistance to the rapid spread of fire, smoke, and fire gases, but it is not likely to collapse.

7. *Height:* The roof and all floors are within reach of any aerial equipment 65 feet or more in length.

8. *Area:* The area is not great enough to create any problems.

9. *Occupancy:* Other than the life hazard mentioned, the occupancy presents no problems. No dangerous materials or processes would be expected.

10. *Access:* The only access problem is that of getting to the rear of the building. Hose lines must be taken to the rear by way of other buildings because there are no alleys or other means of getting into the

yards. This fact is not such a problem for hose lines as it is for ladders. Ladders may have to be taken over the roof and lowered into the backyard, if needed there. There will be difficulty due to all the clotheslines. Parts of the wood fences will have to be removed to get hose lines and other equipment to the back of the building.

11. *Internal protection:* It would be totally lacking in this sort of building.

12. *Water supply:* The water supply appears to be adequate and hydrant spacing is good, but it might be well to have the third-due engine connect to one of the 12-inch mains rather than put three pumpers on the one 6-inch main on Avenue X.

12. *Apparatus:* The three engines should be able to provide all the water needed unless the fire extends to other buildings. The entire building calls for about 1,000 gpm under the ideal-rate-of-flow formula.

The two ladder trucks would have all the ladders needed, because most of the occupants would be using the fire escapes.

14. *Personnel:* Because of the rescue problem and life hazard, the presence of additional firefighters would be desirable. If fire extends into several apartments, several hose lines will be needed.

15. *Terrain:* Not a problem at this fire.

Action Plan

1. *Find the fire:* The fire is visible in the basement.

2. *Rescue:* I would direct the first-due ladder company to raise their aerial ladder to the top floor, aiming for a window where people are showing. At the same time, they should clear any jam of occupants on the fire escape by raising ground ladders to such points.

The second-due ladder company would be ordered to take ladders to the rear and do the same there as the first-due ladder company was told to do in the front. The aerial equipment of the second-due ladder company would be raised to the floor where the need was greatest. (There is no need to raise an aerial to the roof in this case because it is more easily and quickly reached by the stairs of an adjoining building.)

3. *Search:* I would order both ladder companies to start searching for occupants on all floors, starting at the top and working down. Additional units arriving after the first alarm would also be ordered to search. In searching for occupants, firefighters would notice if fire had entered any apartments and should promptly report any such finding. The firefighters on the roof would look down the shaft.

4. *Safety:* There is a potential danger here of being struck by objects thrown out of windows by excited tenants in hopes of saving

them. (*Author's note:* I have actually seen lamps, radios, trunks, and even a large sofa dropped out of tenement windows at fires.)

Breathing apparatus should be used by search teams.

5. *Ventilation:* Quick ventilation at the top of the stairs is of paramount importance to the rescue of occupants; this is necessary to let out the smoke, gases, and heat that quickly gather on the top floor and bank down to other floors if not released. Therefore, members of the first-due ladder company would be sent immediately to the roof by way of an adjoining building to open the door at the top of the stairs and remove other coverings.

6. *Extension protection:* The fire is already on its way up the stairs and can enter any apartment, but it is most likely to do so on the top floor. A line should be taken there via aerial ladder and taken in to the stairs to keep fire from entering.

7. *Entry:* Forcible entry would be required to search apartments that were locked. Ladder company members with forcible-entry tools would be directed to force doors as necessary to complete the search, as they followed the second line up the stairs. Inasmuch as most tenants left by the fire escape or ladders, almost every apartment door would be locked. Therefore, I would order additional forcible-entry tools taken, although in some cases the firefighters entering from the fire escape would obviate the need for forcing apartment doors.

In this type of occupancy, entry through fire escape windows is not always easily obtained. Burglar-proof gates and other types of locks would complicate the problem. The presence of locked fire escape windows is proof that no one had left by that route and is an indication that someone may still be in the apartment. Anyone still in an apartment during this type of fire would be badly in need of aid if not already dead.

The person sent to the roof would have to have a tool suitable for opening the bulkhead door, which probably would be locked on the inside.

8. *Extinguishment:* In this type of fire, lives can be saved by fast, aggressive attack. I would send the first line to the top of the interior stairs leading to the basement with orders to hold that position at all costs. I would then send the second line up the stairs after shooting a straight stream up the stairwell for about ten seconds, because a considerable amount of fire can be killed in a stairwell by that tactic. I would urge the engine company officer to have his company move that line up the stairs as rapidly as possible, while the first line keeps the fire in the cellar from following them. The second line should continue up the stairs until the top floor is reached. Once there, they should enter the rear apartments and kill any fire encountered there, because the line sent up the aerial will enter the front of the building.

Where the doors of the apartments had panels which were destroyed by the fire, it is well to shoot some water into each apartment when passing to kill fire there before moving up to the next floor.

I would order a line into the front basement entrance to extinguish the fire in the basement. I would direct the next-arriving engine company to take another line up the stairs as a backup for the second line. This line would be used to extinguish any fire that had been passed by the second line, which would include that fire remaining in the various apartments as well as that in the stair and hallways.

By this time, the chief of battalion would undoubtedly have arrived. (The question states that I am in charge for ten minutes.) I would tell him what orders I had given and what the status was at the moment, telling also what units had been put to work and where. I would inform him what the situation was like upon my arrival so he can draw his own conclusions as to the progress of the operating force against the fire. I would then venture my own opinion of the situation and from that point on be guided by his orders.

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